

Effect of shade and intercropping in the management of sweetpotato virus disease in Uganda

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Abstract. Experiments were conducted in Uganda for two seasons during 2002 to investigate the effect of intercropping and shade on activities of whiteflies (*Bemisia tabaci*), the main vector of sweetpotato virus disease (SPVD). SPVD is the major disease constraining sweetpotato production in Uganda. The intercrop experiment consisted of the following treatments: sweetpotato sole, sweetpotato + maize, maize sole, sweetpotato + trap, sweetpotato + maize + trap and unplanted plot with trap. Traps were used to monitor whiteflies abundance in different treatments. Traps consisted of bright yellow sticky strip wrapped on 10-cm diameter plastic tubes 30 cm from the ground. For the shade experiment, sweetpotato plots of 5 x 5 m were established with temporary shade made of papyrus mats 1.5 m above the ground. Treatments under the shade trial were sole sweetpotato, sweetpotato + trap, sweetpotato + shade, sweetpotato + shade + trap, shade + trap and empty plot with trap. There were significantly more nymphs and adult whiteflies on sweetpotato in sole than in the sweetpotato maize intercrop plots. Traps located in sole sweetpotato plots also captured higher numbers of whiteflies. However, mean number of plants with SPVD symptoms was similar in intercropped and sole sweetpotato plots. There was no significant difference in storage root yield for intercropped sweetpotato and sole sweetpotato. Maize yield was not affected by intercropping. Shade did not have a significant effect on number of whiteflies, nymphs or infected plants but shaded plots yielded least in both seasons. This work shows that maize may act as a guard crop without being affected or affecting sweetpotato crop yet checking on SPVD vectors, the whiteflies.

Nutritional potential of the under-utilized indigenous root tuber *Nymphaea petersiana* in Malawi

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Abstract. Demographic, health and micronutrient surveys in Malawi show that the nutritional status of the population is very poor, and has not improved during the last decade. Micronutrient malnutrition is particularly severe. For example, sub-clinical vitamin A deficiency was found in 60% of preschool children, 38% of school children, 57% of women of childbearing age and 38% of men. Eighty percent (80%) of pre-school children, 27% of non-pregnant women, and 17% of men were anaemic. The national strategy to deal with this problem is multisectoral intervention involving many collaborating partners. One strategy being promoted is the utilization of readily available indigenous crops. One such indigenous crop is a wild water lily root tuber called “nyika” (*Nymphaea petersiana*), which grows abundantly in the wild in the extensive swamps of the lower Shire river in Chikwawa and Nsanje districts. Nyika tubers are commonly used as sources of food in times

of famine and/or poor harvests. Whole cooked tubers are sold in markets as a snack food, or the tubers are peeled, cut into small pieces, dried and ground into flour. The flour is cooked into nsima, the national dish, which is eaten with different types of stews and vegetables. Nutritional analysis of the Nyika tuber revealed it to be a good source of quality protein (about 8%), limiting only in lysine. Although the fat content is low (1% crude fat), the predominant fatty acids in the tuber were essential fatty acids like oleic (47%), linoleic (37%) and linolenic (7%). More importantly was the high content of iron (100 mg/g of uncooked sun dried tuber). 100 mg of uncooked sun dried tuber supplies approximately 88% of the recommended daily allowance (RDA) of iron in children and 59% of the RDA in women. This amount of iron is higher than the reported values for other common root tubers such as cassava (78 mg/g), potato (7 mg/g) and sweetpotatoes (20 mg/g).

Farmer to farmer cassava varietal selection and breeding: The Domasi experience

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Abstract. In the year 2001 there was a national initiative to enhance the economic role of cassava in Malawi. Stakeholders ranging from farmers to entrepreneurs were invited to attend a symposium that provided impetus for nationally promoting the much-neglected cassava. For the resource poor-farmers this initiative could not have come at a more inappropriate time. There was a severe shortage of cassava planting material and some of the preferred varieties were extinct or at the verge of extinction due to pre-emptive harvesting and diseases. For decades, farmers in Domasi had neglected their cassava due to the generous fertiliser subsidies that had up until the early nineties provided high yields of maize. The decline in fertiliser subsidies forced farmers in Domasi to turn to their “old trusted crop”, cassava. Unfortunately, cassava planting material was/is in short supply food shortage a recurrent problem further compounding the situation. Farmers started mobilizing themselves into clubs in order to secure extra income or food production. Through the active involvement of the chiefs, local society and a Christian community based local NGO the farmers in Domasi have together with researchers and farmers from Mulanje introduced “new” local varieties to the area. The 17 varieties are currently under cassava club farmer field experimental condition. In this paper we present the process of forming cassava clubs and an exchange visit with other cassava farmers in Mulanje district that has enabled the Domasi community to breed 17 locally adapted varieties within one year. The paper discusses mechanisms for improving the co-operation between resource-poor farmer’s and formal agricultural research and extension services.

Determinants of the adoption of improved cassava varieties in Southern Ghana - logistic regression analysis

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Abstract. A benchmark adoption survey under the Root and Tuber Improvement Project of Ghana was conducted in 2001 to provide baseline indicators of adoption and impact for cassava. The sample size of the survey was 150 farmers selected at random from 18 agricultural districts under 5 of the regions of southern Ghana. The adoption rate for improved cassava varieties was 9%. The adoption intensity which is the area under improved cassava cultivation was 37% in the 2001 crop season. The mean size of fields planted to improved cassava by farmers was 3.6 hectares compared with 0.8 hectares by farmers planting local varieties. This means that farmers who plant improved cassava varieties may appear few but cultivate larger field sizes than their counterparts who plant local varieties. For farmers who never used improved cassava varieties, their reasons

were related to availability of improved cassava planting material. Most of them did not know about the improved varieties or could not get them to plant. In a logistic regression analysis to determine the factors affecting the adoption of the improved varieties, land tenure, total field size farmed in 2001 and decisions with extension staff on cassava with farmers had positive and significant effect on the adoption of improved cassava varieties. Years of self-decision on farming and whether farmers had ever bought cassava cuttings were however, negatively related and significant. This suggests that farmers who have recently been in cassava cultivation are more likely to adopt improved cassava varieties than their counterparts with longer experience. Gender and planting arrangement did not have a significant effect although they were positively related.

On-farm pre-treatment of yam tubers to extend shelf life

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Abstract. Yam is an important staple in Ghana and other West African countries such as Benin, Togo and Nigeria. In Ghana, it is mainly consumed in the urban centres and used for various food preparations. In recent times it has become an important non-traditional export crop second only to pineapples. Its major drawback is post-harvest storage/ handling that affects availability, quality and affordability. Pre-treatment of yams prior to storage is considered as one way to overcome the problem. On-farm pre-treatment studies were carried out using three varieties of yam, Pona (Pu), Labareko (Ko) and Lobare (Lo). These were pretreated by dehydrating in the solar chamber dryer for 2 months. Physical observation and sensory evaluation of samples were carried out at various moisture reduction points. Moisture, ash, crude fibre, crude protein, carbohydrate and dry matter of the dehydrated products were determined relative to the fresh samples. Dehydrated samples were then stored for 5 months in yam storage barns traditionally used by farmers. Results of pre-treated samples showed enhanced taste at higher levels of dehydration with decreased mealiness with significant differences between the samples. Pu was the most acceptable variety followed by Ko and Lo. Samples had low crude fibre, ash and protein levels. Moisture content was in the range 64 - 71.35% with appreciable dry matter and carbohydrate levels. For the shelf life studies all varieties could store up to 7 months but Pu had relatively higher rots with Lo having the least. Lo had the highest sprouting (75%) while Ko and Pu had sprout levels of only 18.5 and 20%, respectively.

Land preparation for increased sweetpotato production in Ghana

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Abstract. Sweetpotato in southern Ghana is planted mainly on manually constructed mounds. A land preparation study was initiated on 16 farmers fields in 2001, and advanced to a total of 19 demonstration plots in 2002 and 2003. The objectives were to compare the agronomic feasibility and farmers' perception of manual and mechanized construction of, and management of sweetpotato on ridges with farmers' practices. Planting on ridges resulted in a significant ($P=0.05$) increase (38%) in sweetpotato tuber yield over farmers' practice of planting on mounds under favourable rainfall, as a result of increased number of tubers and crop growth per unit area. Planting on flat land resulted in drastic yield reductions of 28% and 59% from ridges in the major and minor seasons respectively. Farmers' perception of overall ease of manual management was similar for ridges and mounds. However, differences were reported in various aspects of management, with construction being easier on mounds (score=2.6) than on ridges (score=3.3), weeding easier on ridges (score=2.0) than on mounds(2.6), and harvesting easier on mounds (score=1.3) than on ridges(score=1.7) Mechanized ridging, using tractor mounted ridgers was demonstrated on farmers' fields in 2003, and was shown to be much easier and in some areas less expensive to construct than mounding and manual ridging. Ridging has the potential to increase national sweetpotato production through increased yield per unit area, removal of drudgery associated with land preparation, and increase in the acreage under sweetpotato production in Ghana.

Challenges, opportunities, and strategy for cassava sub sector development in Nigeria

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Abstract. Nigeria has substantial economic potential in its agricultural sector. However, despite the importance of agriculture in terms of employment creation, its potential for contributing to economic growth is far from being fully exploited. The sector's importance fluctuates with any rise and fall in oil revenue and has remained stagnant over the past ten years. The contribution of the manufacturing sector to the GDP declined over the same period. Inappropriate macroeconomic and sector policies perpetuated by the 15 years of military rule and mismanagement have had a negative impact, not only on agriculture but also on the entire economy. Presently, Nigeria grows more cassava than any other country in the world. Production has been driven primarily by the demand for food for its nearly 130 million inhabitants while very little is used for feed and industry. Estimates indicate that 52% of cassava output is wasted due to inefficiencies in production and processing, 43% is consumed as food while five percent is used as livestock feed. The question remains whether the country could reduce the amount

wasted by diversifying utilisation to bring down levels of unemployment and rural poverty and enhance economic growth. Using data from primary and secondary sources, the paper assesses the challenges and opportunities in the development of the cassava sub-sector in Nigeria. At the moment, the country does not seem to have a comparative advantage in cassava exports due to inefficiencies in domestic production. There is a need to encourage product diversification to take advantage of the huge domestic and regional markets. The paper recommends a market-led strategy with an emphasis on agroindustrial development and the mobilization of resources through partnerships to improve domestic efficiency and subsequently tap into regional markets in West and Central Africa.

Effect of co-formulated fungicides on late blight management in seed and ware potatoes

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Abstract. Late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important potato disease in Cameroon. Three co-formulated fungicides (Anteor Super, Galben Plus and Ridomil Plus) were evaluated in 2000 for efficacy in suppressing late blight development in seed and ware potato fields. The trial was conducted at Upper-Farm, Bambui (2000 masl). A randomised complete block design was used with four replicates. Three potato varieties (Desirée, Cipira and Tubira) were treated twice with the fungicides at manufacturers' recommended rates. The first treatments were applied at the appearance of the first late blight symptoms (35 DAP) and the second sprays were applied 21 days later. Control plots were not sprayed. Late blight severity varied with fungicide treatment and variety. Low disease intensities

and high seed and ware potato yields were obtained in sprayed plots. The highest yields and net returns were obtained generally in plots treated with Ridomil Plus, followed by Galben Plus. Tuber yields and net returns from fungicidal control varied with fungicidal treatments and variety. Ridomil Plus was the most profitable fungicide, while Anteor Super was the least. Net returns to Ridomil Plus applications varied from US\$ 1,649.27 to 6,949.27/ha for seed potatoes and US\$ 1,400.70 to 2,494.98/ha for ware potatoes. Results show that the co-formulated fungicides used have a potential to suppress potato late blight severity and increase seed and ware potato yields and consequently net farm incomes.

Assessment of genetic diversity, farmer participatory breeding, and sustainable conservation of Eastern African sweetpotato

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Abstract. Sweetpotato [*Ipomoea batatas* (L.) Lam] is one of the most important crops in densely populated East Africa. The crop is vital to small-scale farmers with limited land, labour and capital. A project funded by the Collaborative Crop Research Programme (CCRP) of the McKnight Foundation was initiated from July 2002 to run for four years. Project partners are the Kenya Agricultural Research Institute (KARI), Louisiana State University, The International Potato Center (CIP), Austrian Research Centers-Seibersdorf and the Root and Tuber crops programme of Tanzania. This project aims at improving East African sweetpotato productivity and sustainability through collaborative and participatory research on germplasm conservation, crop improvement, and development of technology for planting material production. So far a total of 679 sweetpotato germplasm accessions have been collected in eight regions of Kenya and Tanzania. Focussed Participatory Rural Appraisals to collect indigenous technical knowledge on sweetpotato germplasm have been conducted in 25 communities in six sweetpotato production regions. Twenty high dry matter and β -carotene rich sweetpotato clones were transferred from CIP-Lima to four SSA countries. A publicly accessible website www.viazitamu.org has been established to support the project, enable online access of germplasm records, as well as share information with the general public. A publicly available, license-and royalty-free, web based GIS viewer for use on the web site has been adapted. Six local orange and yellow fleshed varieties were virus-tested and are being cleaned and multiplied for dissemination to farmers. A number of partner NGOs and CBOs have established field seed multiplication nurseries for distribution as co-funded activities. KARI and LZARDI have also established basic seed nurseries.

Development of a web-accessible GIS database of sweetpotato germplasm for East Africa

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Abstract. Despite the potential of GIS systems to provide vital spatial and temporal information to target clientele, accessibility by users without direct access to these databases is often limited. Web-based delivery represents a method of delivering real-time or near real-time data to clientele. Although proprietary methods are available for delivering GIS data through web interfaces, these methods often require expensive licensing agreements. The availability of publicly available software that require minimal or flexible licensing costs provide a cost-effective alternative to institutions that are considering access to GIS databases via a web-accessible interface. We describe procedures, software, and other applications that we used to develop a publicly accessible web interface to a GIS database of sweetpotato germplasm collections in Kenya, Tanzania, and Uganda.

Development of virus resistant sweetpotato using biotechnological approaches in Kenya

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Abstract. The sweetpotato virus disease (SPVD) is one of the main constraints to sweetpotato production in Africa. It is caused by a number of sweetpotato viruses. The sweetpotato feathery mottle virus (SPFMV) is the most widespread of those viruses. Transformation of sweetpotato plants with viral coat protein genes may impart a coat protein-mediated resistance to SPVD. In 2001 twelve lines of sweetpotato variety CPT 560 transformed with the SPFMV coat protein gene were field tested under controlled conditions in four important sweetpotato growing agro-ecologies in Kenya. Based on virus resistance, yields of storage roots and vines, four transgenic lines were selected and evaluated further in 2002. Results from these field trials did not provide an adequate level of SPVD resistance as expected based on visual assessment of symptoms and tissue printing bioassays. Possible explanations for this unsatisfactory level of protection may be due to synergistic effects of other sweetpotato viruses in the environments where the lines were tested. Secondly it is possible that the first generation gene constructs were not efficient against the Kenyan strains of the virus since they were developed based on American strains of the virus. The second generations of transgenic plants are currently being developed at the Kenya Agricultural Research Institute (KARI) Biotechnology centre and are at various stages of development. These have improved gene constructs developed using Kenyan isolates of SPFMV. This project has been instrumental in development of the biotechnology framework in Kenya and capacity building in biotechnology.

Farmers' participatory perspectives on sweetpotato cultivars in Makueni district of Kenya

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Abstract. Sweetpotatoes are a major source of subsistence and cash income to farmers in semi-arid regions areas of Kenya. KARIKatamani in collaboration with the International Potato Centre (CIP) has been selecting and breeding sweetpotato clones for resistance to major biotic and abiotic stresses. Sixteen promising sweetpotato cultivars were planted at Kampi ya Mawe, Makueni district during the 2001/02 cropping season. The crop was harvested in March 2002 and farmers evaluated the cultivars based on taste and appearance. The best cultivars selected by farmers was Kanziga 2-1,

Mogamba, Bikiramaria, 192100/103, Salyboro and Kanziga 1-1. The farmers' most important selection criteria were taste, appearance and yield in that order. Taste and appearance should be considered when breeders are developing new cultivars

Molecular markers as a tool for participatory cassava breeding

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Abstract. It is of fundamental importance to know the genetic identity of the plants used in the breeding process and in the case of asexually reproduced crops to know to which clone a plant belongs. Since cassava smallscale farmers do not maintain a one-to-one relationship between variety and clone participatory cassava breeding has a problem using farmer's plants. This study uses molecular markers to identify clones popular by small-scale cassava farmers and to describe the impact of genotype by environment interaction (GxE) on farms. Popular clones are particularly important when choosing local parents for crossings. Better knowledge of GxE at the farm level would improve the selection schemes. Eight SSR markers were found to be sufficient to discriminate between clones. A wide diffusion of a clone was used as an estimate of its popularity. Plants were collected from ten districts of Malawi. Most clones were limited in their geographic distribution. A majority was represented by a single plant but a few were found in several districts. Plants of the clones 'gomani' and 'mbundumali', that for decades have been distributed by the national breeding programme, were collected from farmers in three and nine districts, respectively. There was genetic identity between all 'gomani' collected from the farmers and the 'gomani' in the breeding programme. Plants that belonged to the program clone 'mbundumali' had seven variety names among farmers and these varieties also included a fraction of other clones. Consequently farmers can maintain varieties as single clones but mostly molecular markers are needed for identification of a plant's genotype. The study also suggests that the major part of the small-scale farmers' clones is used for breeding the rest for production. The analysis of GxE in farmers' fields showed that interaction occurred within farms for variables related to cultivation activities as well as to natural environmental variation.

Improving productivity and household incomes of resourcepoor farmers: The case of cassava-cowpea intercrop

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Abstract. Intercropping is a widespread practice in tropical developing countries. The cassava-cowpea intercrop system was identified as one of the major four cropping systems in the forest and southern Guinea savanna zones of West and Central Africa. The objectives of the study were to evaluate the relative times of planting cowpea, cowpea row arrangement and cassava variety in cassava/cowpea intercrop in farmers' fields on: (a) the crop productivity of the systems, (b) assess their economic return and (c) identify those suitable for further on-farm demonstrations and transfer to farmers. Cassava/cowpea intercrops were tested on farmers' fields in 2000-2002 in the transition and coastal savannah zones of Ghana for sustained crop productivity and household incomes. An incomplete block design was used to assign a factorial combination of three cassava varieties, two relative times of planting and three row arrangements to farmers' fields. The 1 row Afisiafi cassava or local cassava combined with 2- or 3-rows of Asetenapa cowpea; with Asetenapa planted 4 weeks after cassava were the most productive systems. Productivity (LER) over the sole crops ranged from 41% for Afisiafi to 113% for the local variety. Abasafitaa, Afisiafi and local cassava planted 4 weeks before Asetenapa yielded 41-51%, 67-87% and 109- 112% of sole crop, respectively. Asetenapa yielded 20% higher under the local than the improved cassava varieties. Averaged over both years, the 1 row cassava (all varieties)/ 2 rows cowpea with cowpea planted 4 weeks after cassava system gave the highest benefit/ cost ratio (2.72-3.56) and net benefits (¢2.25 million - ¢3.35 million) over the other intercrop systems and the sole crops. Sole cowpea gave the lowest benefit/cost ratio (1.50) and net benefits (¢627,000.00).

The use of doubled-haploids in cassava breeding

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Abstract. Cassava breeding is difficult and, compared with other crops, inefficient. The problems in cassava breeding relate to the length of the breeding cycle, the large genetic load present in the crop, and the heterozygous nature of the parents and progenies evaluated. The production of doubled haploids, through tissue culture techniques, offers interesting advantages. By definition, any process that involves increased homozygosity will result in a decrease of genetic load. Doubled-haploid lines, therefore, are expected to produce better hybrids. Furthermore, the availability of homozygous lines would allow for a gradual and consolidated breeding to improve parental performance in hybrid combinations. This means that the genetic enhancement will benefit from previous gains, like steps in a staircase. The breeder “owns” the genetic superiority of an inbred progenitor but that is not necessarily the case with heterozygous parents, particularly in heterozygous crops like cassava. With the introduction of doubled-haploids, the emphasis of cassava breeding shifts from producing large number of hybrids (hoping to find a superior one) to improving parents for the production of better hybrids that are “*designed*”, not just found. In addition to these advantages doubledhaploids will facilitate discovery and exploitation of recessive traits and germplasm conservation. One important additional advantage is that germplasm exchange could be greatly facilitated, thus helping to bridge the relative isolation in which cassavabreeding projects in different countries currently operate.

Farmers decide: A participatory approach to the development and dissemination of improved cassava technologies that increase yields and prevent soil degradation

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Abstract. Farmers in Asia like to grow cassava because the crop tolerates long dry periods and poor soils, and produces reasonable yields with little inputs. Most farmers realize, however, that cassava production on slopes can cause severe erosion, while production without fertilizer inputs may lead to a decline in soil productivity. Research has shown that cassava yields can be maintained for many years with adequate application of fertilizers, and that there are various ways to reduce erosion. Adoption of erosion control practices, however, has been minimal as farmers generally see little short-term benefits of these practices. To enhance the adoption of soil conserving practices and improve the sustainability of cassava production, a farmer participatory research (FPR) approach was used to develop not only the best soil conservation practices, but also to test new varieties, fertilization and cropping systems that tend to produce greater short-term benefits. The FPR methodology was initially developed in 2-3 sites each in China, Indonesia, Thailand and Vietnam, but has now extended to about 99 villages in Thailand, Vietnam and China. The methodology includes the conducting of RRAs in each site, farmer evaluation of a wide range of practices shown in demonstration plots, FPR trials with farmer-selected treatments on their own fields, field days with discussions to select the best among the tested practices, scaling-up to

larger fields, and farmer participatory dissemination to neighbors and other communities. Based on the results of these trials, farmers have readily adopted better varieties, fertilization and intercropping practices, and many farmers have now adopted the planting of contour hedgerows to control erosion. The resulting increases in cassava yields in Asia over the past eight years have increased the annual gross income of cassava farmers by an estimated 150 million US dollars.

Introduction

Cassava (*Manihot esculenta* Crantz) is usually grown by smallholders in upland areas with poor soils and low or unpredictable rainfall. In some countries, the crop is grown on steep slopes, but in others it is grown mainly on gentle slopes; in both cases, soil erosion can be serious. Moreover, cassava farmers seldom apply adequate amounts of fertilizers or manures to replace the nutrients removed in the harvested products. Thus, both erosion and nutrient extraction can result in a decline in soil fertility and a gradual degradation of the soil resource.

The fact that farmers do not apply sufficient fertilizers and do not use soil conservation practices when the crop is grown on slopes is more a socio-economic rather than a technical problem. Research has

shown many ways to maintain or improve soil fertility and reduce erosion, but farmers usually consider these practices too costly or requiring too much labor. To overcome these obstacles to adoption, it is necessary to develop simple practices that are suitable for the local situation and that provide short-term benefits to the farmer as well as long-term benefits in terms of resource conservation. Being highly site specific these practices can best be developed by the farmers themselves, on their own fields, in collaboration with research and extension personnel.

Thus, a project was initiated, with financial support from the Nippon Foundation in Tokyo, Japan, to develop a farmer participatory methodology for the development and dissemination of more sustainable production practices in cassava-based cropping systems that will benefit a large number of poor farmers in the uplands of Asia.

Materials and Methods

First Phase (1994-1998). The first phase of the project was conducted in four countries, i.e. China, Indonesia, Thailand and Vietnam. The project was coordinated by CIAT and implemented in collaboration with research and extension organizations in each of the four countries. During an initial training course on farmer participatory research (FPR) methodologies, each country designed a work plan to implement the project. The steps in the process, from diagnosing the problem to adoption of suitable solutions, are shown in Figure 1. The outstanding feature of this approach is that farmers participate in every step and make all important decisions.

(a) Pilot site selection. Suitable pilot sites were pre-selected in areas where cassava is an important crop, where it is grown on slopes and erosion is a serious problem. Detailed information obtained through Rapid Rural

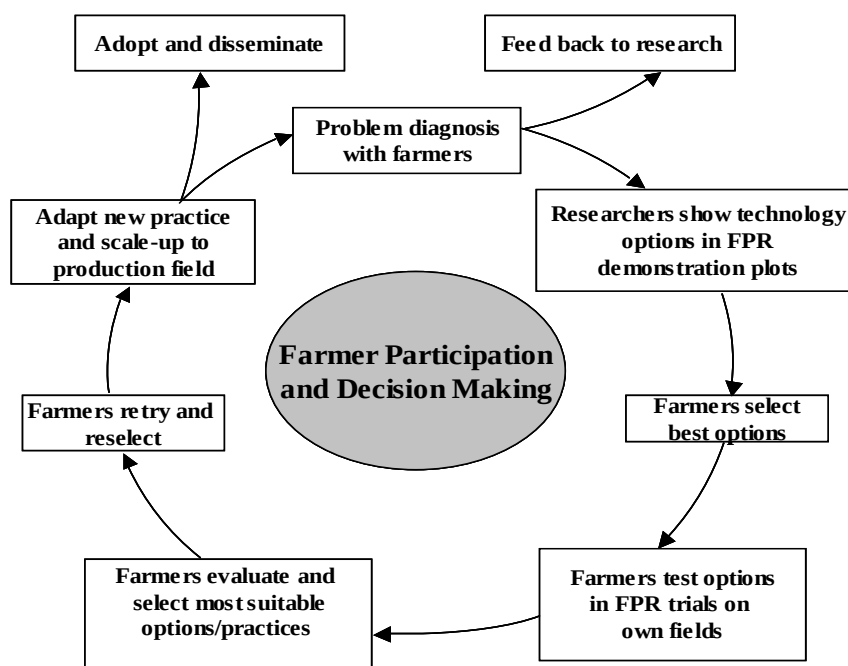


Figure 1: Farmer participatory model used for the development of sustainable cassava-based cropping systems in Asia.

Appraisals (RRA) in each site have been reported by Nguyen The Dang *et al.* (1998), Utomo *et al.* (1998), Vongkasem *et al.* (1998) and Zhang Weite *et al.* (1998). After conducting the RRAs, one or two suitable pilot sites (villages or sub districts) were selected to work with farmers in the development and dissemination of suitable varieties and production practices.

(b) Demonstration plots. Each year demonstration plots were laid out on an experimental station or a farmer's field to show the effect of many alternative treatments on yield, income and soil erosion. Farmers from the selected pilot sites visiting the trial were asked to discuss and score the usefulness of each treatment. From this range of many options farmers usually selected 3-4 treatments that they considered most useful for their own conditions. Some farmers then volunteered to test these treatments in FPR trials on their own fields.

In both the demonstration plots and FPR erosion control trials on farmers' fields, a simple methodology was used to measure soil loss due to erosion in each treatment. Plots were laid out along the contour on a uniform slope; along the lower side of each plot a ditch was dug and covered with plastic. Small holes in the plastic allowed runoff water to seep away, while eroded sediments remained on the plastic. These sediments were collected and weighed several times during the cropping cycle. After correcting for moisture content, the amount of dry soil loss per hectare was calculated for each treatment. This simple methodology gives both a visual as well as a numerical indication of the effectiveness of the various practices in controlling erosion (Howeler, 2001; 2002).

(c) FPR trials. The FPR trials did not only involve soil conservation practices, but also new varieties, intercropping systems and fertilization, with the objective of developing a combination of practices that would increase farmers' income, reduce erosion and improve soil fertility.

During the first phase of the project, farmers in the four countries conducted a total of 177 FPR erosion control trials, 157 variety trials, 98 fertilizer trials and 35 intercropping trials. At time of harvest, field days were organized in each site to harvest the various trials by the participating farmers and their neighbors. The yields of cassava and intercrops, the dry soil loss due to erosion, as well as the gross income, production costs and net income were calculated for each treatment and presented in a joint meeting to the farmers. After one or more years of testing in small plots, farmers quickly identified the best varieties and production practices for their area and started using those on larger areas of their production fields (Howeler, 2002).

Second Phase (1999-2003). The second phase of the project was conducted in collaboration with five institutions in Thailand, six in Vietnam and three in China. During the second phase the emphasis shifted from participatory research (FPR) to extension (FPE) in order to reach more farmers and achieve more widespread adoption. These farmer participatory extension activities included the organization of cross-visits, in which farmers from a "new" site visited those from an "older" (already established) site where FPR trials were being conducted or where some selected practices had already been adopted. It also included training courses for key farmers and local extensionists; farmer field days at time of harvest as well as large-scale farmer field days with participation of many farmers from the district or province, and the establishment of community-based self-help groups. In addition, more conventional extension tools, such as a video, and booklets on various aspects of cassava production and utilization were prepared.

Once farmers had selected certain practices and wanted to adopt those on their fields, the project staff tried to help them; for instance, in setting out contour lines to plant hedgerows for erosion control, or to obtain

seed or vegetative planting material of the selected hedgerow species, intercrops or new cassava varieties.

Results and Discussion

First Phase (1994-1998): Farmer Participatory Research (FPR)

(a) FPR trials. Table 1 shows a typical example of an FPR erosion control trial conducted by six farmers having adjacent plots on about 40% slope. It is clear that contour hedgerows of vetiver grass, *Tephrosia candida* or pineapple reduced erosion to less than 20% of that in the check plot, while intercropping with peanut and planting vetiver hedgerows markedly increased net income. Results of many other FPR trials have been reported by Nguyen The Dang *et al.* (2001), Huang Jie *et al.* (2001), Utomo *et al.* (2001) and Vongkasem *et al.* (2001).

(b) Scaling-up and adoption. After having selected the most promising varieties and production practices from FPR trials, farmers generally like to test some of these on small areas of their production fields, making adaptations if necessary. Some practices may look promising on small plots, but are rejected

as impractical when applied on larger areas; this may be due to lack of sufficient planting material (like vetiver grass) or lack of markets for selling the products (like pumpkin or lemon grass).

Second Phase (1999-2003): Farmer Participatory Research (FPR) and Extension (FPE)

Since the objective of the second phase was to achieve widespread adoption of more sustainable production practices by as large a number of farmers as possible, it was necessary to markedly expand the number of pilot sites and to develop farmer participatory extension (FPE) methodologies to disseminate the selected practices and varieties to many more farmers.

In subsequent years, the project was expanded. In 2001 the project was being implemented in about 50 sites. This was further increased to 99 sites by the end of the project in 2003 (Figure 2). Once the benefits of the new technologies became clear, the number of sites increased automatically, as neighboring villages also wanted to participate in order to increase their yields and income.

Whenever the project extended to a “new” site, the process outlined above was re-

Table 1: Results of an FPR erosion control trial conducted by six farmers in Kieu Tung village, Thanh Ba district, Phu Tho, Vietnam, in 1999.

Treatment ¹	Slope (%)	Dry soil loss (t/ha)	Yield (t/ha)		Gross income ²	Product costs ³	Net income
			cassava	Peanut			
_____ (mil. dong/ha) _____							
1. C monocult., with fertilizer, no hedgerows	40.5	51.8	26.3	-	10.52	3.04	7.48
2. C+P, no fertilizer, no hedgerows	45.0	25.1	11.5	0.45	7.07	4.45	2.62
3. C+P, with fertilizer, no hedgerows	42.7	33.7	18.6	0.47	10.02	5.26	4.76
4. C+P, with fertilizer, <i>Tephrosia</i> hedgerows	39.7	6.2	23.8	0.49	12.21	5.26	6.95
5. C+P, with fertilizer, pineapple hedgerows	32.2	10.5	24.0	0.66	13.23	5.26	7.97
6. C+P, with fertilizer, vetiver hedgerows	37.7	8.0	33.8	0.37	15.55	5.26	10.29
7. C monocult, with fert., <i>Tephrosia</i> hedgerows	40.0	3.3	21.7	-	8.68	3.04	5.64

¹ Fertilizers = 60 kg N + 40 P₂O₅ + 120 K₂O/ha; all plots received 10 t/ha pig manure.

² Prices: cassava dong 400/kg fresh roots, peanut 5500/kg dry pods. ³ Cost fertilizers = 0.810 mil. dong/ha; cost of intercropping = 2.22 mil.dong/ha.

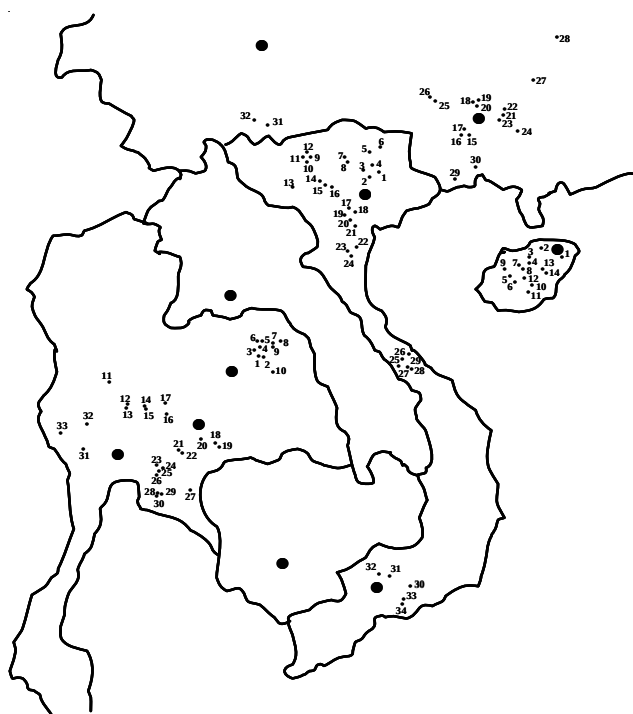


Figure 2: Location of FPR pilot sites in China, Thailand and Vietnam in the Nippon Foundation cassava project in 2003.

initiated, i.e. an RRA was conducted, interested farmers visited demonstration plots and/or made a cross-visit to an already established site, and they conducted FPR trials, discussed results and eventually adopted those varieties or practices they had selected as most suitable for their own conditions. Table 2 shows the number and type of FPR trials conducted in China, Thailand and Vietnam during the second phase of the project. While initially farmers were mainly interested in testing new varieties, fertilization, intercropping and erosion control practices, during the later part of the project they also wanted to test the use of organic or green manures, weed control, plant spacing and even leaf production and pig feeding. During the second phase of the project a total of 1,154 FPR trials were conducted by farmers on their own fields.

The following farmer participatory extension methods were found to be very effective in raising farmers' interest in soil

conservation, in disseminating information about improved varieties and cultural practices, and in enhancing adoption of soil conserving practices:

(a) Cross-visits. Farmers from new sites were usually taken to visit older sites that had already conducted FPR trials and had adopted some soil conserving technologies. These cross-visits, in which farmers from the older site could explain their reasons for adopting new technologies was a very effective way of farmer-to-farmer extension. After these cross-visits, farmers in some new sites decided to adopt some technologies immediately, while others decided to conduct FPR trials in their own fields first. In both cases, the "FPR teams" of the various collaborating institutions, together with provincial, district or sub district extension staff, helped farmers to establish the trials, or they provided seed or planting materials required for the adoption of the new technologies.

Table 2: Number of FPR trials conducted in the 2d phase of the Nippon Foundation Project in China, Thailand and Vietnam.

Country	Type of FPR trial	1999	2000	2001	2002	2003	Total
China	Varieties	9	9	20	69	20	127
	Erosion control	3	5	8	17	-	33
	Fertilization	-	-	-	4	-	4
	Intercropping	-	-	-	9	-	9
	Pig feeding	-	-	-	59	-	59
		12	14	28	158	20	232
Thailand	Varieties	11	16	16	19	25	87
	Erosion control	14	10	6	-	11	41
	Chemical fertilizers	16	6	23	17	17	79
	Chem.+org fertilizers	-	-	10	11	11	32
	Green manures	-	-	13	11	15	39
	Weed control	-	-	17	5	10	32
	Plant spacing	-	-	3	-	2	5
	Intercropping	-	-	16	7	-	23
		41	32	104	70	91	338
Vietnam	Varieties	12	31	36	47	35	161
	Erosion control	16	28	29	30	23	126
	Fertilization	1	23	36	24	24	108
	Intercropping	-	14	32	31	26	103
	Weed control	-	3	-	-	3	6
	Plant spacing	-	1	7	19	8	35
	Leaf production	-	-	2	2	1	5
	Pig feeding	-	-	11	16	13	40
		29	100	153	169	133	584
Total		82	146	285	397	244	1,154

(b) Field days. At time of harvest, field days were organized at the site in order to harvest the trials and discuss the results. Farmers from neighboring villages were usually invited to participate in these field days, to evaluate each treatment in the various trials and to discuss the *pros* and *cons* of the various practices or varieties tested. In a few cases, large field days were also organized with participation of hundreds of neighboring farmers, school children, local and high-level officials, as well as representatives of the media. The broadcasting or reporting about these events also helped to disseminate the information about suitable technologies. During the field days, farmers explained the results of their own FPR trials to the other

visiting farmers, while literature about the project and the results obtained was distributed.

(c) Training. Research and extension staff involved in the project had previously participated in Training-of-Trainers courses in FPR methodologies, including practical training sessions with farmers in some of the pilot sites. While some participants were initially skeptical, most course participants became very enthusiastic about this new approach once they started working more closely with farmers.

In addition, 2-3 key farmers from each site together with their local extension agent were invited to participate in FPR training courses.

The objective was to learn about the various FPR methodologies, the basics of doing experiments as well as the implementation of commonly selected technologies, such as setting out contour lines or the planting, maintenance and multiplication of hedgerow species. By spending several days together in these courses, the farmers and extensionist got to know each other well, and they were encouraged to form a local “FPR team” to help other farmers in their community conduct FPR trials or adopt the new technologies.

(d) Community-based self-help groups.

Realising that effective soil conservation practices, such as planting of contour hedgerows, can best be done as a group, farmers from some sites decided to form their own “soil conservation group”. These community-based self-help groups are similar to “Land Care units”, that have been very effective in promoting soil conservation in the Philippines and Australia. In Thailand, farmers are encouraged farmers to set up these groups as a way of organizing themselves, to conduct FPR trials, to implement the selected practices, and to manage a rotating fund, from which members of the group can borrow money for production inputs. Thus, by 2003, a total of 21 “Cassava Development Villages” had been set up in the pilot sites. Each group needed to have at least 40 members, elect five officers to lead the group, and establish their own bylaws about membership requirements, election of officers, use of the rotating fund, etc. The formation of these groups helped to decide on collective action and to strengthen the community, while people gained confidence and the group became more self-reliant. When necessary, the group could request help from local or national extension services, obtain information about certain production problems, or get planting material of vetiver grass or other species for hedgerows or green manures. Some groups started their own vetiver grass nurseries to have planting material available when needed.

(e) Adoption and Impact. After conducting their own FPR trials, or after a cross-visit to another village where those trials were being conducted, farmers often decided to adopt one or more technologies on their production fields with the hope of increasing yields or income and protecting the soil from further degradation.

In Thailand, practically all of the cassava area is now planted with new varieties and about 75% of farmers apply some chemical fertilizers (TTDI, 2000), although usually not enough nor in the right proportion. As a result of the FPR fertilizer trials, farmers started to apply more K, while the official fertilizer recommendation for cassava was changed from an NPK ratio of 1:1:1 to 2:1:2. After trying various ways of controlling erosion, most farmers selected the planting of vetiver grass contour hedgerows as the most suitable. Table 3 indicates that by the end of 2003, about 865 farmers had planted a total of 1.65 million vetiver plants, corresponding to about 150 km of hedgerows.

Table 4 similarly summarizes the adoption of various new technologies in Vietnam. In 2001, over 1400 farmers in the FPR pilot sites were planting new cassava varieties (mainly KM 94), while hundreds were applying more balanced fertilization (usually pig manure in addition to chemical fertilizers), intercropped with peanut or black bean, and controlled erosion by the planting of contour hedgerows of *Tephrosia candida*, vetiver grass or *Paspalum atratum*. In some villages in Pho Yen district of Thai Nguyen province in North Vietnam, the gross income of many farmers in 2001 was 4-5 times higher than those reported in 1994/95 at the start of the project (CIAT, 2001). During 2002 and 2003 farmers in Van Yen district of Yen Bai province in North Vietnam planted a total of 500 km of double hedgerows of *Tephrosia candida* or *Paspalum atratum* to control erosion, and they planted about 3000 ha of new cassava varieties with improved fertilizer practices. This increased average yields from 10 t/ha to about 30 t/ha.

Table 3: Extent of adoption of vetiver grass contour hedgerows for erosion control in various FPR pilot sites in Thailand in 2003.

Province		District	Sub district	Adoption of vetiver grass			
				Cassava		Vetiver	
				No. of farmers	area with vetiver (ha)	(no. of plants)	hedgerows (km) ¹⁾
1.	Kalasin	Mueang	Phuu Po	61	49.0	85,500	8.6
2.	Kalasin	Mueang	Khamin	-	-	-	-
3.	Kalasin	Nong Kungsri	Nong Bua	67	110.4	111,600	11.2
4.	Kalasin	Sahatsakhan	Noonburi	63	59.2	86,170	8.6
5.	Kalasin	Sahatsakhan	Noon Nam Kiang	47	40.6	128,330	12.8
7.	Kalasin	Naamon	Naamon	50	24.0	56,000	4.0
8.	Kalasin	Huay Phueng	Nikhom	50	24.0	216,000	20.0
9.	Kalasin	Don Chaan	Dong Phayung	50	24.0	28,500	2.2
10.	Roy Et	Phoo Chai	Khampha-ung	-	-	4,000	0.4
11.	Kamphaengphet	Khanuwaralakburi	Bo Tham	42	27.2	68,000	3.0
12.	Chayaphum	Thep Sathit	Naayaang Klak	42	27.2	83,000	5.5
14.	Nakhon Ratchasima	Thepharak	Bueng Prue	-	-	-	-
15.	Nakhon Ratchasima	Thepharak	Bueng Prue	26	34.2	80,000	11.0
16.	Nakhon Ratchasima	Sri Khiw	Paang Lako	-	-	-	-
17.	Nakhon Ratchasima	Daan Khun Thot	Baan Kaw	53	49.4	130,000	15.0
18.	Nakhon Ratchasima	Soeng Saang	Noon Sombuun	62	132.5	80,000	20.0
19.	Nakhon Ratchasima	Soeng Saaang	Sratakhan	-	4.8	20,000	2.0
20.	Nakhon Ratchasima	Khonburi	Tabaekbaan	27	24.0	100,000	5.0
21.	Prachinburi	Naadii	Kaeng Dinso	34	27.2	60,000	4.5
23.	Chachoengsao	SanaamChaikhet	Thung Prayaa	32	10.4	50,000	2.0
24.	Chachoengsao	Thaa Takiap	Khlong Takraw	42	27.2	100,000	5.3
27.	Sra Kaew	Wang Sombuun	Wang Sombuun	75	220.8	90,000	9.0
28.	Chonburi	Bo Thong	Kaset Suwan	-	-	-	-
31.	Ratchaburi	Baan Poong	Khaw Khalung	-	-	-	-
32.	Kanchanaburi	Law Khwan	Thung Krabam	42	27.2	80,000	3.0
33.	Kanchanaburi	Sai Yook	Sai Yook	-	-	-	-
Total	11	22	25	865	943.3	1,657,100	153.1

¹Cassava area with hedgerows and hedgerow length are approximate, as some hedgerows were damaged by tractor while others needed to be partially replanted because of poor establishment due to drought.

Table 5 indicates the extent of adoption of new varieties in China, Thailand and Vietnam, both in terms of cassava area planted and the number of farmers planting these varieties. Only a fraction of the more than 800,000 farmers planting new varieties had actually participated in the project; the others must have heard about new varieties from extension agents, other farmers, starch factories or TV. In Thailand about 98% of the total cassava area is now planted with new varieties; in Vietnam this is about 40% and in China about 10%. Table 6 shows that during the past eight years the average cassava yields in all three

countries increased; this increase ranged from 0.83 t/ha in China to 4.16 t/ha in Vietnam. The increased yields resulted in annual increases in gross farmers' income by about 100 million US dollars in the three countries, and about 150 million US dollars in the whole of Asia. In addition, farmers in Thailand received higher prices due to the higher starch content of the new varieties. This was achieved by the collaborative effort of many researchers, extensionist, factory owners and farmers with strong support from national governments. The development of high yielding improved varieties and more efficient agronomic and soil

Table 4: The adoption of new technologies by farmers in various sites in Vietnam in 2001.

Province	District	Village	Adoption (no. farmers/ha)				
			Varie- ties	Fertili- zation	Erosion control	Inter- cropping	Silage making
Thai Nguyen	Pho Yen	Tien Phong	81/4.7	45/2.3	4/0.2	40/1.5	-
		Dac Son	22/0.7	15/0.8	3/0.1	8/0.5	-
		Minh Duc	30/0.9	25/0.7	3/0.3	25/1.6	-
		Hong Tien	26/1.0	-	-	-	-
		Van Phai	26/0.3	-	-	-	-
		Nam Tien	7/0.2	-	-	-	-
Thuong Am commune							
Tuyen Quang	Son Duong	Am Thang	16/2.0	15/0.5	15/6.0	-	-
		Hong Tien	18/1.2	18/0.6	8/4.0	-	-
Yen Bai	Van Yen	Yen Hung	5/2.0	-	5/2.0	-	-
		Yen Thai	4/2.0	-	4/2.0	-	-
		Yen Hop	6/2.0	-	6/2.0	-	-
		Mau Dong	9/4.0	-	9/2.0	-	-
		Dong Cuong	7/2.0	-	7/2.0	-	-
		Tan Hop	5/2.0	-	5/2.0	-	-
		Dong An	6/2.0	-	6/2.0	-	-
		Lam Giang	4/2.0	-	4/2.0	-	-
		An Binh	7/2.0	-	7/2.0	-	-
Phong Linh commune							
Phu Tho	Thanh Ba	Kieu Tung	13	-	25	-	-
Thong Nhat commune							
	Phu Ninh	Thong Nhat	32/2.0	-	25/3.5	-	-
		Bao Thanh	5	-	-	2	-
Dong Xuan commune							
Hao Binh	Luong Son	Dong Rang	-	12	45	9	-
Ha Tay	Thach That	Thach Hoa	1000/ 100	10	15	4	-
Tran Phu commune							
Chuong My	Tran Phu	40	-	-	60	-	
Thua Thien-Hue	A Luoi	Hong Ha	>19	12	25	>20	15
Nam Dong	Thuong Long	10	-	-	-	20	
Huong Tra	Huong Van	-	-	-	-	40	
Dong Nai	Thong Nhat	An Vien	>30	2	-	5	-
Binh Phuoc	Dong Xoai	Dong Tam	-	5	-	5	-
		Minh Lap	-	10	-	5	-
Baria Vungtau	Chau Duc	Suoi Rao	7/1.4	-	5/2.0	-	-
Total		30	>1,435	169	226	>183	75

Table 5: Estimation of the number of farmers that have adopted and benefited from new cassava varieties in China, Thailand and Vietnam.

Country	Province	Average cassava areaper household(ha) ¹	Area undernew varieties (ha)	Average no.of farmers adopting new varieties ²
China	Guangxi	0.22	16,666	75,500
	Guangdong	0.53	~6,000	~11,320
	Hainan	0.53	1,333	2,500
Thailand		2.86	1,000,000	350,000
Vietnam		0.27	100,000	370,000
Total				~809,320

¹Data estimated from RRA (1994) and Vietnam Cassava Survey (1991/92)

²Assuming complete replacement of old by new varieties.

Table 6: Estimation of the annual increase in gross income due to higher cassava yields resulting from the adoption of new cassava varieties and improved practices, in China, Thailand and Vietnam, as well as in Asia as a whole.

Country	Total cassava area	Cassava yield (t/ha) ¹		Yield increase	Cassava price	Increased gross income due to higher yields
	(ha) ¹	1994	2002	(t/ha)	(\$/tonne)	(mil. US \$)
China	240,100	15.21	16.04	0.83	24-30	5.4
Thailand	1,030,000	13.80	16.38	2.58	21-24	59.8 ²
Vietnam	329,900	8.44	12.60	4.16	22-29	35.0
Asia total	3,486,502	12.93	14.67	1.74	25	151.7

¹Data from FAOSTAT 2003.

²In addition, farmers also benefited from higher prices due to higher starch content.

conservation practices, as well as the use of a farmer participatory approach, all contributed to the widespread adoption of new varieties and improved practices in many countries in Asia resulting in improved livelihoods of cassava farmers.

Conclusions

Research on sustainable land use conducted in the past has mainly concentrated on finding solutions to the bio-physical constraints, and many solutions have been proposed for improving the long-term sustainability of the

system. Still, few of these solutions have actually been adopted by farmers, mainly because they ignored the human dimension of sustainability. For new technologies to be truly sustainable they must not only maintain the productivity of the land and water resources, but they must also be economically viable and acceptable to farmers and the community. To achieve those latter objectives farmers must be directly involved in the development, adaptation and dissemination of these technologies. A farmer participatory approach to technology development was found to be quite effective in developing

locally appropriate and economically viable technologies, which in turn enhances their acceptance and adoption by farmers.

The conduct of FPR trials is initially time consuming and costly, but once more and more people are trained and become enthusiastic about the use of this approach - including participating farmers - both the methodology and the selected improved varieties or cultural practices will spread rapidly. The selection and adoption of those farming practices that are most suitable for the local environment and in tune with local traditions will improve the long-term sustainability of the cropping system, to the benefit of both farmers and society at large.

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Plant water relations and photosynthetic properties of polyploid cassava grown in the Nigerian savanna

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Abstract. Cassava (*Manihot esculenta* Crantz) genotypes of varying ploidy levels (diploid, triploid and tetraploid) were investigated for their plant water relations and photosynthesis to better understand the modalities of selecting for adapted and high yielding genotypes. Data from trials conducted in the savanna agroecological zones of Nigeria were used for this purpose. Anatomy and stomatal morphology showed significant genotypic and ploidy differences. Water use efficiency, stomatal resistance and carbon exchange rates elucidated significant ploidy differences as well as genotypic differences in physiological behavior. Stomatal parameters gave an array of sensitivity and resistance to water deficit stress suggesting desirable selection indices. This paper presents satisfactory and contradictory factors associated with the use of photosynthesis and water relations in an attempt to select for improved productivity in an intensive agroecological zone-based breeding program for cassava.

Nutrition and utilization of a new sweetpotato cultivar for tops

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Abstract. A new variety, Suioh, was released for vegetable use by the National Agricultural Research Center for Kyushu Okinawa Region, Japan in 2001. The nutritional value of the flour made from the tops of Suioh and the characteristics of its processed foods, bread and green tea, were evaluated to develop a new use of sweetpotato tops. The protein, lipid, sodium, iron, zinc, carotene, total ascorbic acid, vitamin E, and vitamin K₁ contents were the highest in the leaves. The highest content of ash, potassium and carbohydrate were the highest in petioles or stems. The dietary fiber, energy, phosphorous and magnesium contents did not much differ among the portions. The contents of the components in each portion of the tops in the Jul. 15 harvests did not change appreciably in Aug. 27 harvests. The flour from whole tops, consisting of leaves, petioles and stems, seemed to have a well-balanced nutritional value. Addition of flour from whole tops at 2% of the bread ingredients was the optimal amount for swelling, color, hardness and bread aging in bread processing. The green tea made from the tops contained high amount of polyphenols and showed high activity of radical scavenging activity. Thus, sweetpotato tops can be used as an ingredient of processed foods and green tea in addition to its use as a leafy vegetable.

Screening of local cassava varieties against cassava mosaic disease and cassava green mite

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Abstract. One of the sustainable solutions in controlling cassava mosaic disease (CMD) is the deployment of resistant genotypes. In this study, fifty cassava varieties mostly local landraces collected from the Lake Zone were screened for resistance to CMD and GCM. The varieties were evaluated in high disease pressure areas of Geita district in a randomized complete block design in two replications in two seasons. Cassava genotypes were obtained from the cassava germplasm bank at ARI Ukiriguru and were planted at a spacing of 1.0m x 1.0m in plots measuring 10.0m x 2.0m. Disease incidence and severity were taken at three months intervals. In the first year, 40% of the genotypes were severely infected by the disease. Many of these were therefore eliminated. The varieties that were

retained exhibited significant differences in disease levels ($P < 0.05$). The most resistant varieties were Kachaga and Lwamilembe. Their CMD severity scores were 1.5 and 1.0, respectively. Root yield for the two varieties were 10.1kg/plot and 6.2kg/plot, respectively. These yields were higher than those of the rest of the varieties. Varieties that had high CMD severities also gave low root yields. The varieties Kachaga and Lwamilembe were therefore recommended for areas with heavy CMD infection

The role of community based organisations, NGOs and farmers in technology transfer

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Abstract. Cassava (*Manihot esculenta* Crantz) and sweetpotato (*Ipomoea batatas*) are key food crops in Tanzania in general and in the lake zone in particular. Cassava and sweetpotato are household food security crops in addition to being a source of household income. Availability of the new improved varieties to farmers has been a problem in Tanzania. A project was initiated to transfer improved varieties of both cassava and sweetpotato in the lake zone to farmers. In collaboration with community-based organisations (CBOs), non-government organisations (NGOs) and farmer groups, the project distributed different varieties of cassava and sweet potato in Shinyanga and Mwanza regions through CIP/ASARECA. The CBOs, NGOs and farmer groups were very instrumental in facilitating the delivery of improved varieties to farmers. Through this informal seed delivery system using CBOs, NGOs, and farmers groups, farmers have been able to access, use and adopt improved varieties suitable for their areas. The project has also established a system that can be used for future technology transfer activities. Through this system more than 988,000 and 1,752,711 cuttings of improved cassava and sweet potato varieties, respectively, were distributed in three regions of the lake zone. The distribution activity went hand in hand with training of farmers in rapid multiplication techniques of planting materials.

Introduction

Cassava and sweet potato are the most important roots and tuber crops in the lake

zone and in Tanzania in general. The crops are grown mainly for home consumption with the excess sold to generate income. In Tanzania, the major growing areas are found in the lake zone while in southern zone the major producing regions are Mtwara, Lindi and Ruvuma. Other important production areas are Tanga and Kigoma (Msabaha and Rwenyagira, 1989). Sweet potato is grown almost everywhere in the country although production differs from one place to another.

With the outbreak of cassava mosaic disease, the need for planting materials especially in the Lake Zone of Tanzania has become great. This has triggered the need to have a system for multiplying and distribution of clean planting materials. In 1999, the ASARECA-CIP technology transfer project was initiated in the lake zone. The aim of the project was to multiply and distribute to farmers improved varieties of both cassava and sweet potato that combine resistance to major biotic stresses and other desirable traits. The project also aimed at establishing a system that could be used for future technology transfer activities.

Methodology

The project recognised and involved farmers in the project. Farmers selected fields for multiplying the crops. From these fields, planting materials were harvested and distributed to individual farmers within the group for further multiplication. At harvest individual farmers retained 50% of the planting materials for further multiplication. The rest of the materials was given to other members

of the group. This arrangement was facilitated by a formal contract between the project and individual farmers. The project involved six partners from different organizations. These partners are described below:

Plan international (Mwanza Branch). This NGO is involved in agriculture, youths, education and health. Its main role was to purchase and distribute sweet potato planting materials around Mwanza Municipality. It also supervised farmer groups and organized training for extension staff and farmers.

CARE International (Magu district). This is an NGO involved in agriculture. Their role was to organize farmers in establishing village secondary multiplication sites. The NGO purchased and distributed cassava and sweet potato from the research station and also facilitated the training of both extension staff and farmers.

Bukoba District Rural Development Programme (BDRDP). This organisation concentrate on activities that aim at improving household food production in Bukoba. In this project, its role was to establish secondary multiplication plots at farmer extension centres (FECS). It also purchased and distributed sweet potato and cassava planting materials.

International Potato Centre (CIP). The main role of CIP was to provide technical backstopping on project planning and regular monitoring of the project.

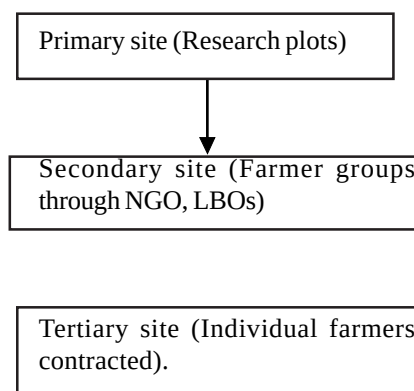
Tanzania Home Economics Association (TAHEA). This is a local NGO which is involved in household food security and agricultural technology transfer activities. Its role was to organize secondary multiplication sites and prepare training programs for farmers.

Masalakulangwa (CBO). This is a community based organisation which is

involved in both agricultural and environmental activities. Members were involved in multiplication and distribution of planting materials.

Achievements. Farmers in the project area now have access to improved varieties of both sweet potato and cassava. The widely adopted cassava varieties are: TMS 4(2) 1425, Msitu Zanzibar, and TMS 83/01762 (b) while for sweet potato, the adopted varieties include SPN/0 (simama), sinia and mavuno SP/93/94.

Farmers now earn money from the sale of both roots and planting materials. This is the first record of farmers earning money from planting materials in the zone. Another achievement of this project was the establishment of a system of multiplication and distribution of planting materials for the two crops and will be exploited for future technology transfer activities. The system is summarised below:



This system creates a sense of variety ownership by farmers and increases the chances of variety adoption. Linkage with various stakeholders has been strengthened. These linkages enhanced cost sharing, and thus made technology transfer overall cheaper.

Lessons learned. Some important lessons were learnt from this project. Increased food

production without market outlets can defeat the whole purpose of introducing improved technologies. Therefore sub-sector analysis is important before embarking on a large – scale multiplication of planting materials. This analysis will identify constraints and find solutions early enough. When farmers get involved in all stages of the project, they get a sense of ownership which makes them committed to the technology and promotes sustainability of the technology. Market forces can change cultural traditions. The high demand for planting materials of improved varieties encouraged farmers to pay for these materials. This resulted into farmers earning some income and motivated them to grow large areas and hence increasing the chances of wide distribution of improved varieties.

Recommendation

A holistic integrated approach linking farmers to market must be adopted to make technology transfer effective and sustainable.

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Breeding cassava for brown streak resistance: Regional cassava variety development strategy based on farmer and consumer preferences

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Abstract. Cassava is an important food crop in the East African coastal lowlands. However, yields are low due to various reasons amongst which are pests and diseases. Cassava brown streak virus disease (CBSD) is one of the major diseases of economic importance in Kenya, Tanzania, Mozambique and Malawi. Yield losses attributed to CBSD ranging from 49 – 74% have recently been reported in some coastal areas of Tanzania. It is estimated that in Tanzania alone, CBSD causes economic losses of more than USD 16,000,000 annually. The wide adoption of resistant varieties is the best sustainable control strategy. However, only a hand full of resistant/tolerant varieties is available in each of the severely affected countries. In order to increase the number of resistant varieties available to farmers, a seedling nursery was raised at Kibaha, Tanzania. About 513 seedlings were selected and cloned for further evaluation. At Kibaha, CBSD disease pressure and spread was very high therefore, 88% of the harvested seedlings were infected. This indicated that this site was ideal for screening cassava genotypes for resistance to CBSD. Although the vector is still unknown, it was very active and infective at this site. Because the seedlings were raised from botanical seeds, ruling out the chance of vegetative plant material transmission, these results prove that vector transmission can account for a large percentage of plants infected in a field. Families with a high percentage of number of seedlings selected (PNSS) included Kiroba, 71762 and I88/00188. The importance of marking diseased seedlings during the growing season is discussed. Furthermore, massive introduction of germplasm through open quarantine, the establishment of crossing blocks to generate improved genotypes and the use of a decentralized participatory evaluation procedure have been initiated as important strategies towards availing farmers with a wider choice of improved varieties.

Substitution of hominy meal with cassava root meal as a source of energy for growing dairy heifers

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Abstract. An experiment was carried out to evaluate the effect of cassava (*Manihot esculenta*) root meal (CRM) and fish wastes (FW) on the growth of dairy heifers in four rations. The rations were TR₁ (66.5 % HM and 31.5 % CSC) TR₂ (50 % CRM and 48 % CSC) TR₃ (67.5 % HM and 30.5% FW) and TR₄ (51.5% CRM and 46.5 % FW). Twenty Ayrshire heifers (average weight 145±8 kg) were randomly allocated to the four rations in a completely randomized block design. Data was collected on dry matter intake (DMI), weight gain, glucose, Ca, P and protein blood levels. No difference (P>0.05) in weight gain was observed between heifers on TR₁ and TR₃. Heifers on TR₂ showed faster growth rates (P< 0.05) than those in other treatments (i.e. 620 versus 490, 460 and 410 g for TR₁, TR₃ and TR₄ respectively). Correspondingly heifers on TR₂ had superior (P< 0.05) feed efficiency (0.116) followed in a descending order by TR₁, TR₃ and TR₄ (0.097, 0.092 and 0.085 kg gain / kg feed. Heifers receiving diets containing FW had higher (P<0.05) Ca and P than those on CSC. Blood glucose and plasma protein were higher (P<0.05) in heifers receiving TR₁ (97.07g/l and 3.3 mmol/l) than those on TR₂ (94.86 g/l and 3.0 mmol/l). It is concluded that CRM could be used alone as energy source when combined with protein rich feeds like CSC and FW.

A new sweetpotato cultivar, “quick sweet” has an altered starch structure and low gelatinization temperature

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Abstract. “Quick Sweet” is a new cultivar released for fresh market use in Japan. It was derived from a cross between “Beniazuma” and “Kyushu 30.” The gelatinization temperature of “Quick Sweet” starch is about 20 °C lower than those of ordinary cultivars including its parents. Its starch granules show an abnormal morphology characterized by cracking into granules. Analyses of the chainlength distribution of amylopectin determined by high-performance anion-exchange chromatography (HPAEC) showed that “Quick Sweet” starch had a higher proportion of short chains (DP 6 - 11) compared to those in normal sweetpotato starch. The change in chain length distribution of amylopectin is thought to be the reason for the unique starch properties of “Quick Sweet”. Because of these starch properties, the storage roots can be cooked more quickly than ordinary cultivars. Eating quality of “Quick Sweet” after microwaving is also good. Ordinary cultivars do not taste nice after micro-waving. It is thus expected to be a convenient cultivar for the busy Japanese.

Improvement and popularization of diversified cassava products for income generation and food security: A case study of *Kibabu*

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Abstract. *Kibabu* is a traditional plain deep fried cassava product prepared from cassava paste. It was noticed however that the product was deficient in nutrients and that there was also room to improve product acceptability. A study was conducted to improve nutrient content and palatability of traditional *kibabu*, using 80% cassava and other staple mixture and 20% onion-garlic inclusion in the formulation. Laboratory analysis and sensory evaluation were conducted on *kibabu* from each of the formulations. Results showed that use of groundnuts and soybeans improved the nutritive value while the incorporation of coconut improved palatability of *kibabu* significantly ($P < 0.05$). Plain cassava *kibabu* was poor in nutrients and rich in energy. Once blended with groundnuts or soybean, however, its nutrient content improved greatly. The dry matter of the formulated product ranged from 70.36 to 90.34%. On dry weight basis, the nutrient content was as follows: crude protein, 1.21-19.69; fat, 6.74- 41.51% and ash content, 1.96-12.45%. The fibre content ranged from 5.46-25.85%, with coconut contributing most to this increase. The improvement resulting from blending with coconut was not outstanding except for fat and protein. Incorporation of high levels of soybean in the formulation increased the protein content greatly, but it also introduced the bean flavour that lowered the acceptability of the resulting *kibabu*. Blending coconut, groundnuts and/or soybeans could result in a product that is acceptable in addition to being nutritionally balanced.

Cassava in Tanzania: A famine or commercial reserve?

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Abstract. Tanzania is one of the largest cassava producers in Africa. About 655,700 ha of land are under cassava with a total annual production of about 1,795,400 tons. Cassava is a staple food crop in most of the semi-arid and the frequently drought stricken areas. For this reason cassava has traditionally been considered a famine reserve crop. The main objective of this paper is to provide evidence that there is an opportunity to change the role of cassava in most farming systems in Tanzania. That cassava is becoming an important source of income (a cash reserve). The paper is based on case studies undertaken in selected villages in

Tanzania. The results show that cassava producers/processors can earn as much as Tanzanian shillings 170,000 per month from cassava. This amount is more than three times the minimum wage in Tanzania.

Virus diseases of root crops in Africa: An overview

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Abstract. Virus diseases are some of the most economically important constraints to the production of the root crops: cassava, sweetpotato and yams in sub-Saharan Africa. Cassava is affected primarily by two virus diseases: cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). CMD, caused by a group of cassava mosaic begomoviruses, is present in all cassavagrowing areas of Africa, on average affects half of all plants, and is responsible for continent-wide losses in excess of US\$ 1 billion annually, arguably making it globally the most important plant virus disease. This impact is currently being exacerbated by a pandemic of an unusually severe form of the disease. CBSD, caused by cassava brown streak virus, an ipomovirus, is most important in coastal East Africa where it leads to lost production through producing a brown necrotic root rot. Recent reports suggest it may also now be damaging cassava in parts of central Africa. Sweetpotato in Africa is attacked by a large number of viruses, although only two are of major economic importance. Sweetpotato chlorotic stunt virus, a crinivirus, and Sweetpotato feathery mottle virus, a potyvirus, commonly occur in sweetpotato plants in mixed infection, giving rise to sweetpotato virus disease (SPVD). In farmers' fields, incidences of greater than 30% are frequent, particularly in the Lake Victoria

zone of East Africa, where the disease is most damaging. However, perhaps SPVD's most pernicious effect is to prevent farmers growing superior high-yielding genotypes, particularly ones from outside Africa, as these are generally extremely susceptible to it. Yam is similarly affected by a broad range of viruses, but the most widespread and economically damaging is Yam mosaic virus (YMV), a potyvirus, which occurs throughout the major yam-producing zone of West Africa, commonly at incidences in excess of 50%. Other potyviruses, a badnavirus (*Dioscorea alata* virus), and other viruses (including a cucumovirus and a comovirus) cause leaf symptoms that result in chronic and sometimes severe tuber losses. Whilst the virus threat to African root crops appears to be as great as ever, substantial progress has been made in developing control methods, most notably through the development of virus resistant germplasm and by identifying appropriate cultural controls. The challenge for the future will be to combine these approaches into integrated management strategies and ensure that they reach the producers for whose livelihoods these root crops are so essential.

Nutritive value of fresh cassava tubers, cassava root meal and cassava chips for growing - finishing pigs

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Abstract. Three experiments were carried out to evaluate the nutritive value of fresh unpeeled cassava tubers, peeled, soaked cassava tubers, cassava root meal and cassava chips as energy sources for growing/finishing pigs. The varieties used were sweet and bitter types. The initial weight of the pigs ranged from 12 to 38 kg and were slaughtered when they made 90 kg. Their feed intake, growth rate and carcass characteristics were determined. The digestibility trial involved 4 castrated males in a 4x4 Latin square design. Performance of pigs was comparable to pigs fed other energy sources (or commercial cereal based diet). Pig growth rate ranged from 478 to 660 g/pig /day. Digestibility and feed efficiency of cassava-based diets were high, although young pigs (below 20 kg) tended to develop gastro-intestinal disturbances and parakeratosis when fed fresh cassava. The

carcass quality was slightly affected. Carcasses from pigs fed on cassava diets were leaner and heavier than those on other rations. The studies concluded that varieties of sweet cassava could be fed fresh to pigs either peeled or unpeeled or in form of cassava chips. Further, fresh cassava can be soaked in water for one day whereas cassava chips can be dried for 8 to 10 hours prior to feeding to reduce HCN levels. Cassava can constitute the only energy source in diets of pigs provided that such diets are well balanced for protein, minerals and vitamins. The use of cassava in livestock feeds will promote cassava production and provide a sustainable outlet for this underutilised but highly

adaptable crop.

Nutritional evaluation of composite flour based on root and tuber crops and sensory acceptability of the developed products

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Abstract. A study was conducted to evaluate the nutritive value of composite flour based on root and tuber crops and sensory acceptability of the developed products. Fresh tubers and roots of cocoyam, sweetpotato and cassava, respectively, were washed separately, peeled and sliced. The sliced pieces of each crop were soaked separately in water for 1-2 h to reduce toxic and anti-nutritional factors and sun dried for 4-5 days. The dried slices were milled and sieved. The flour was used in the formulation of six types of composite flour for the preparation of baked products and weaning foods. The formulated mixtures included: cocoyam: wheat: soybeans (50:20:30), cassava: wheat: soybeans (50:20:30), sweetpotato: wheat: soybean (50:25:25), cocoyam: maize:soybean (50:20:30), cassava: maize: soybean (50:25:25), sweetpotato: maize: soybean (50:25:25). The nutritive content of formulated flour mixtures contained 9.96 to

15.60, 67.98 to 74.11, 2.57 to 3.19 and 1.66 to 2.89 percent of protein, carbohydrate, fat and crude fibre, respectively. Mineral content of formulated mixtures ranged from 13.0-480.0 mg/100g for iron, calcium, phosphorus, and magnesium while the energy value ranged from 360.07 to 363.13 kcal. Sensory acceptability of the products developed from the formulated flours was carried out to assess taste, texture, smell, colour and general acceptability using a five point hedonic scale. Breads and porridges prepared were generally accepted in terms of taste, texture, smell and colour. It was therefore concluded that flour from root and tuber crops can be blended with cereal and legume flours to produce weaning foods and baked products.

Reprise des recherches sur le manioc au Congo suite a la pandemic de la mosaïque africaine de manioc

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Résumé. A la suite des troubles, la République du Congo a connu, à partir de 1999, une recrudescence des maladies graves (mosaïque et bactériose) sur le manioc. La situation de la production de manioc a été gravement détériorée provoquant de grandes pénuries dans les grands centres de consommation urbains et dans certaines zones rurales. Une intervention de l'IITA soutenue par l'USAID a été orientée sur la lutte contre la maladie pandémique de la mosaïque en 2002 et 2003. Dans le cadre de cette intervention, un certain nombre d'activités ont été engagées, notamment la diversification et l'échange de germoplasme, la conduite des essais Tests/Evaluation en différentes zones écologiques, et, la multiplication des clones tolérants pour la mise à la disposition des paysans des

boutures à planter. Les résultats préliminaires obtenus présentent des clones performants comme le clone 92/277 et méritent d'être renforcés par d'autres introductions et évaluation pour endiguer la mosaïque du manioc en Afrique centrale.

Evaluation agronomique et économique du système de production améliorée des semenceaux d'igname à partir des minifragments au Centre Bénin

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Résumé. Une étude a été conduite dans la région des savanes du Bénin dans les zones dégradées et moins dégradées. L'étude avait pour but d'identifier le mode de prégermination approprié pour la technique de minifragmentation et d'évaluer les aptitudes agronomiques et économiques des variétés d'igname à cette technique. Les résultats de l'étude ont révélé des réponses variables selon les variétés. Le mode de prégermination à même le sol sous abri (arbres) apparaît plus indiqué par rapport à l'usage du panier pour la technique de minifragmentation des semenceaux. Des pertes sensibles de minissets étaient observées dans les strates inférieures des paniers (du deuxième strate au quatrième strate). Aucun effet substrat n'a été observé pendant la phase de pépinière ni après transplantation des semenceaux en champs paysans. Parmi les variétés testées appartenant au complexe *Dioscorea cayenensis-rotundata*, la variété *Gangni* à deux récoltes présentait une bonne aptitude agronomique à la technique de minifragmentation par rapport à *Kokoro* (à une récolte) et *Yanabo* (à deux récoltes). La variété *Gangni* affichait sur le site de Akpéro (site moins dégradé) une production de 9,45 t ha⁻¹ contre 5,58 t ha⁻¹ et 4 t ha⁻¹ respectivement pour *Kokoro* et *Yanabo*. Sur le site de Miniffi (site dégradé), le rendement était de 3,1 t ha⁻¹ pour *Gangni* et 0,82 t ha⁻¹ pour *Kokoro* avec une différence significative au seuil de 5%. Les rendements et les composantes de rendements étaient relativement élevés à Akpéro liés à une fertilité plus élevée des sols. La baisse de rendements en général observée était liée au retard de pluie qui a conduit au retard de transplantation des semenceaux d'igname affectant ainsi leur cycle de production. La production traditionnelle des semenceaux d'igname pour les variétés *Gangni* et *Yanabo* est rentable dans les nouvelles défriches (système de défriche brûlis) avec un ratio bénéfice coût de 1,5 unités. Elle n'est pas rentable pour *Kokoro*. Le système amélioré de production d'igname à partir des minifragments dans les anciennes défriches (champ traditionnel en culture continue) est également rentable pour les variétés *Gangni* et *Yanabo* avec un ratio bénéfice coût de 1,5 comparable à celui observé dans les nouvelles défriches. Les variétés *Gangni* et *Yanabo* présentent une valeur marchande intéressante et sont économiquement attractives pour la technique de production améliorée des semenceaux d'igname. Sur la base des résultats obtenus, il serait souhaitable de recommander les techniques d'amélioration de la fertilité des sols dans les anciennes défriches avec l'utilisation des légumineuses herbacées ou arbustives. Des recherches méritent d'être menées dans le domaine de l'organisation de la filière, de la production jusqu'à la commercialisation des semenceaux d'igname. Quelques approches sont proposées dans le présent document.

Abstract. A study was carried out in Savannah area of Benin in degraded and less degraded soil. The goal of study was to identify the appropriate mode of nursery and evaluate (agro-economic assessment) the minissets production system. Three varieties of (*Dioscorea cayenensis-rotundata* complex) such as *Gangni*, *Yanabo* (varieties of two harvestings), *Kokoro* (variety of one harvesting) and two support (soil and basket) containing sandy soil or sawdust were used at nursery phase. After germinating, the minissets were transplanted on farmers' fields. The results showed variables responses for varieties. The germinating mode on the soil (under trees) seems to be adequate for the minissets technique compared to the use of basket. The sensitive loss of minissets was observed on inferior steps of the baskets (from 2 to 4 steps). No significant effect of substrate was observed during the germinating and transplanting phases. Among varieties tested, *Gangni* expressed interesting agronomic aptitude for minissets technique compared to the others. In less degraded soil (Akpéro), *Gangni* tubers yield raised 9,45 t ha⁻¹ against 5,58 t ha⁻¹ and 4 t ha⁻¹ for *Kokoro* and *Yanabo* respectively in traditional continuous cropping system. At Miniffi, degraded soil, the tuber yield was significant (5%) ranged 3,1 t ha⁻¹ and 0,82 t ha⁻¹ for *Gangni* and *Kokoro*. The yield and its components are relatively higher in less degraded soil related to the initial soil fertility level. In general, yields are low because of rainy fall perturbation which led to the late of transplanting and the loss of minissets; this affecting production cycle. Traditional dominant system of yam seed production in slash

and burn system (shifting cultivation system) was profitable for *Gangni and Yanabo* varieties with benefit cost ratio of 1,5 but not profitable for *Kokoro*. The improved seed yam in traditional continuous cropping system was equally profitable for *Gangni and Yanabo* varieties with benefit cost ratio of 1,5 compared to the result observed in slash and burn system. Both varieties are economically attractive for minisettis technique. On the basis of these results, techniques for improving soil fertility with the use of herbaceous or woody legumes are to be recommended in traditional continuous cropping system. Researches have to be focussed also on the organisation mechanism including production and commercialization for promoting the sector. Some approaches are proposed in this document.

Rural household expenditures for roots and tubers in South Western Nigeria: An almost ideal demand system analysis

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Abstract. This paper analyzes rural household expenditure patterns on root and tuber-based products in the forest and savanna zones of southwestern Nigeria. A multistage sampling technique was used to select 252 respondents in two communities during the 2001-2002 period. Daily data on household expenditure were collected over two weeks in each quarter of the year. In addition, demographic characteristics of households were collected. Data were analyzed using descriptive statistics and the Almost Ideal Demand System (AIDS) model. Respondents' mean age was 42 years in the forest and 54 years in the savanna. Education level was low: only 8.3 years (forest) and 4.52 years (savanna). Mean household size was 7 in the two ecologies. Household expenditure was 83% of mean income in the forest and 100% in the savanna. Contrary to expectations, food accounted for 21.5% of household expenditure for the forest and 15.5% for the savanna despite a major share of harvest being used for home consumption. Major root and tuber-based products identified were: *gari/eba*, cassava flour, *fufu*,

amala, boiled yam, pounded yam, and cocoyam. There was no major difference in household budget expenditure patterns on these commodities in the two ecologies, though the total budget allocation to roots and tubers was higher in the forest zone. Own price elasticity estimates show that some products are price elastic, many are income elastic, while others have positive cross price effects (substitutes) or negative effects (complements). Demographic factors significantly influenced decisions on household budget allocation, particularly in the forest zone. Budget shares and elasticity estimates of commodities may assist in the construction of cost of living indices. Linking farmers to growth markets will ensure sustainable root and tuber production to meet the country's food sufficiency objective.

Adaptability and acceptability of new orange-fleshed sweetpotato varieties in selected areas of Eastern and Central zones of Tanzania

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Abstract. Orange-fleshed sweetpotato (OFSP) has been earmarked to be among food-based approaches in providing cheap source of beta-carotene a precursor of Vitamin A. Orange coloration intensity in sweetpotato roots correlates positively with the amount of beta-carotene available. In Tanzania, sweetpotato is produced almost entirely for home consumption and majority of popular varieties are either white or yellow-fleshed, which don't qualify to provide enough vitamins to meet the daily requirements. Majority of sweetpotato growers are resource poor with limited access to expensive sources of Vitamin A. Severe deficiency of Vitamin A has been reported to contribute to about 60 percent mortality rates for preschoolers (children aged under 5 years) and pregnant/lactating mothers in South Asia and sub Saharan Africa. In Tanzania, production and utilization of OFSP is limited, hence there was a need to test the adaptability and acceptability of the newly introduced varieties by farmers to ensure wide acceptance hence increased utilization. Twenty improved orange fleshed varieties introduced from CIP in 2001 were evaluated at Kibaha (lowland warm sub-humid) and Hombolo highland warm semi-arid) research stations. Two local checks were included. At harvest, farmers were invited to conduct the acceptability studies so as to capture the consumer-desired qualities. Varieties Tainung-65 (440215) and Japon Tresmesino (420009) produced significantly high yields at both sites. Carrot-

C (local check) gave the least yields. All varieties tested showed mild symptoms of virus disease. Results on farmer's assessment revealed that, among the varieties, Tainung-65, Jonathan, Zapallo and Centennial had generally higher acceptance levels. Others were rejected due to low dry matter, inability to produce enough planting materials especially during the dry season and some due to low yields. Varieties Tainung 65, Jonathan, Zapallo and Centennial have therefore been selected for on-farm testing.

Introduction

Sweetpotato (*Ipomoea batatas*. Lam) is grown throughout Tanzania and is the third most important root and tuber crop after cassava (*Manihot esculenta*) and round potato (*Solanum* spp.). The crop occupies approximately 14 percent of total arable land of the farms surveyed (Kapinga *et al.*, 1995). Consumption of sweetpotato is mostly by boiling; roasting and deep-frying of the roots and the leaves are blanched and used as vegetable.

Vitamin A deficiency (VAD) is the world's most common cause on child blindness (Mukherjee *et al.*, 2002). WHO estimates 228 million children affected sub clinically and 500,000 children become partially/totally blind every year as a result of Vitamin A deficiency. Low *et al.* (2001) reported that, in Sub Saharan Africa (SSA) and Asia, there are severe deficiency of Vitamin A leading to high fatality

rates of 60 percent for preschoolers (children under 5 years of age) and pregnant/lactating mothers. In SSA, estimates of VAD children aged 5 range from 24% to 70% (Harvey and Taylor, 2003).

Promotion of the consumption rate of OFSP at community level is a food-based approach that aims at combating Vitamin A deficiency especially for women and children. Most of sweetpotato growers are resource poor, therefore consume imbalanced diets. Among Vitamin A rich foods, OFSP provides a cheap source of Vitamin A (Low *et al.*, 2001). Orange coloration intensity in sweetpotato root flesh indicates its level of β -carotene (van Jaarsveld, 2003).

Most of sweetpotatoes grown by farmers are white fleshed. Experience indicates that, most of the orange-fleshed sweetpotato varieties currently grown by farmers have low root yields accompanied by low dry matter contents (Mwanga *et al.*, 2003b). High dry matter content is among the major criteria used by farmers in the selection of sweetpotato varieties in Tanzania; especially in the Eastern zone farming communities (Masumba *et al.*, 2003). Therefore there was a need to introduce OFSP varieties adapted to Tanzania conditions and also acceptable to consumers.

Objectives. The following objectives were targeted:

- To introduce and evaluate orange-fleshed varieties.
- Assess consumer acceptability of the introduced orange fleshed varieties.
- Assess the adaptability of the introduced varieties in the two agro-ecologies (lowland warm sub humid and highland warm semi-arid areas).
- To increase the diversity of OFSP to combat Vitamin A deficiency at community level.

Materials and Methods

Tested varieties. Twenty OFSP varieties including the local checks namely Mayai and Carrot-C were used (Table 1).

Research locations. The varieties were evaluated on station for their general performance in terms of their virus reaction, root yield and adaptability. Two different agro-ecologies were identified and used for rapid evaluations of the introduced varieties. These were the lowland warm sub-humid (Kibaha), about 107 meters above sea level with sandy clay loam soils. It is characterized by a weak bimodal pattern of rainfall of an average of 970mm per annum. The second was a highland warm semi-arid (Hombolo) area about 1070 meters above sea level with reddish loamy soils. This area experiences a

Table 1: Twenty orange-fleshed varieties of sweet potato introduced from International Potato Center (CIP), Kenya in 2001.

Variety	CIP number
1. Tainung No. 65	440215
2. Tainung No. 64	440189
3. W-123	440018
4. W-151	440005
5. VSP-3	440287
6. VSP-4	440228
7. Jewel 38	56638
8. Jewel 31	440031
9. TIB	440060
10. Resisto	187017
11. Salyboro	187017
12. Excel	440016
13. BP-SP-2	440293
14. Kandee	440140
15. Zapallo	420027
16. Jonathan	420014
17. Julian	440141
18. CN 317	440090
19. Japon tresmesino	420009
20. Nemanaje	-
21. Centenial	440122

monomodal rainfall pattern with an average rainfall of about 655mm per annum.

Experimental design. A replicated preliminary yield trial was established during the long rains in April 2002 (Kibaha) and January 2003 (Hombolo). This is the common sweetpotato growing season in the respective areas. Plot size was 1.0m x 6.0m and plants spaced at 0.3m as intra-row spacing (i.e., 20 plants per ridge, two/four rows per variety).

Consumer acceptance by farmers. A total of 26 (Eastern zone) and 30 (Central zone) sweetpotato farmers were invited for participatory sweetpotato variety selection at Kibaha and Hombolo research stations, respectively. They were involved in the assessment of the post harvest attributes of the varieties including appearance, taste, mealyness, fibrousness and general acceptability. Clones were assessed by individual farmers using a subjective scale (1=very poor, 2=poor, 3=moderate, 4=good and 5=excellent) (Kapinga *et al.*, 2000). By the use of matrix ranking procedure mean scores were ranked. Farmer opinions on individual clones were computed into frequencies. Scores of the clones were compared using means.

Data collection and analysis. Data collected included plant establishment, virus scores, foliage and root yield (number, weight of the storage roots and dry matter content). A CIP scoring method was adopted and data subjected to the Analysis of Variance (ANOVA) using Mstat-C package.

Results and Discussions

Plant establishment and sweetpotato virus disease reaction. Generally establishment rates at Kibaha were higher with the average of 97.4 % as compared to Hombolo 75.5% (Table 2), probably as a result of semi arid condition the latter location experiences. At Kibaha all the varieties had good establishment rate of above 90.0% except for Julian (440141)

(80.0%). The same variety Julian could not be established at Hombolo because it dried off after planting.

Reaction to sweetpotato virus diseases. Results on severity scores for sweetpotato virus disease ranged between class 2 (mild symptoms on a few plants) and 4 (mild symptoms on many plants, stunting of many plants). Generally, Salyboro and the two local checks (Carrot-C and Mayai) had the lowest scores displaying its mild resistance to the disease (Table 2). The rest of the introductions succumbed to the disease. Kibaha site was however less affected by SPVD than Hombolo. Virus pressure in the region, has slowed down the uptake and promotion of OFSP as noted earlier studies (Kapinga *et al.*, 1995; Kapinga *et al.*, 2003; Mwanga *et al.*, 2003a) and Laurie *et al.*, 2003). CIP however in collaboration with other research organizations has developed new varieties high in dry matter content and beta-carotene with good resistance to sweetpotato virus diseases. These varieties will be introduced in Tanzania soon (Kapinga *et al* 2003, Mwanga *et al* 2003b).

Plant vigour and foliage weight. Most of the varieties had intermediate vigour (class 3). Tainung 65 had the highest plant vigour (class 5 for Hombolo site) followed by the local checks Mayai and Carrot-C (Table 3). Hombolo site gave the lowest yields because of the dry weather as compared to Kibaha site. The amount of rain for the two cropping seasons at Kibaha was abnormally low and erratic.

Root yield and dry matter content. High root yields is among the best criteria that farmers base on in the selection of crop varieties. Average root yields that reported by the Tanzanian Ministry of Agriculture and Food Security are as low as 2.0 t/ha. In this study, at Kibaha site, almost 50% of the total introduced varieties produced higher yields than the local varieties (Table 4). Varieties Salyboro, Japon, Tresmesino, Tainung 65 and

Table 2: Plant establishment of orange fleshed sweet potato varieties and their reaction to virus diseases at Kibaha and Hombolo stations , Tanzania (2002/2003).

Variety/clone	CIP number	Plant establishment (%)		Sweetpotato virus disease evaluation	
		Kibaha	Hombolo	Kibaha	Hombolo
Tainung 64	440189	100.0	78.3	2	4
Jonathan	420014	97.5	76.3	4	4
Salyboro	187017-1	100.0	70.9	2	2
Centenial	440112	92.5	61.6	2	4
W-123	440018	-	73.4	3	4
W-151	440005	92.5		3	4
Zapallo	420027	92.5	79.1	2	4
Jewel 31	440031	100.0	84.0	3	4
VSP-4	440228	97.5	68.9	4	4
Nemanete	-	100.0	86.4	2	4
Kandee	440140	100.0	83.4	3	4
CN 317	440090	97.5	26.5	3	4
Tainung 65	440215	100.0	85.3	2	3
VSP-3	440287	97.5	72.5	4	4
TIB	440060	100.0	82.8	4	4
Jewel 38	56638	100.0	80.8	3	4
Resisto	440001	97.5	65.9	3	3
Excel	440016	100.0	81.0	2	4
Japon Tresmesino	420009	100.0	84.0	2	3
Julian	440141	80.0	-	2	-
Carrot-C	Local check	100.0	73.8	2	2
Mayai	Local check	100.0	95.0	2	2

SPVD scores: 1= No visible symptoms; 5= Completely attacked by virus.

VSP 65 gave higher yields at both sites. Majority of the tested varieties had high dry matter contents (beyond 30% at both sites). Varieties Tainung 64, Nemanete, W-123, CN-317 and Centenial although low yielders gave higher dry matter contents.

Consumer acceptability by farmers: A good number of varieties (55%) tested at both locations were highly accepted by consumers for good taste and other root attributes (Tables 5 and 6). Majority were appreciated for being “dry” as the local ones.

Conclusion and implications

The results showed that OFSP varieties were accepted at both trial sites in Tanzania indicating wide adaptability and acceptability.

Varieties Salyboro, Tainung 65, Japon Tresmeniso, Jonathan, Zapallo, Excell and Kandee are doing well even in other parts of Tanzania, Kenya, South Africa, and Mozambique (Kulembeka *et al.*, 2003; Kapinga *et al.*, 2003; Laurie *et al.*, 2003). These have not been successful in the Lake Victoria Crescent of Uganda because of the high virus pressure (Mwanga *et al.*, 2003). This implies that careful recommendations should be made taking these exceptional cases into consideration. While research continues on breeding to combine multiple resistances to stress factors, most of the introduced varieties can be promoted in low virus pressures. Also breeding programs should target to raise populations using African landraces or improved African germplasm that are already adapted to various stresses. Examples are

Table 3: Plant vigour and foliage weights of the evaluated varieties of orange-fleshed varieties of sweet potato at Kibaha and Hombolo, Tanzania in 2002/3 and 2003/4.

Variety/clone	CIP number	Plant vigour		Foliage weight (t/ha)	
		Kibaha	Hombolo	Kibaha	Hombolo
Tainung 64	440189	3	3	7.7	5.1
Jonathan	420014	3	2	10.0	4.5
Salyboro	187017-1	3	3	11.7	5.0
Centenial	440112	3	1	9.3	1.2
W-123	440018	3	2	-	3.3
W-151	440005	3	—	12.0	-
Zapallo	420027	3	3	11.0	5.0
Jewel 31	440031	3	3	10.7	4.7
VSP-4	440228	3	3	13.0	4.8
Nemanete	-	2	3	6.0	5.5
Kandee	440140	3	2	4.3	3.1
CN 317	440090	2	1	6.7	1.3
Tainung 65	440215	3	5	15.3	5.2
VSP-3	440287	3	3	12.3	4.5
TIB	440060	3	3	6.0	1.9
Jewel 38	56638	3	2	4.0	2.5
Resisto	440001	2	3	3.0	2.0
Excel	440016	3	3	7.7	3.9
Japon Tresmesino	420009	3	3	14.0	4.6
Julian	440141	2	-	2.7	-
Carrot-C	Local check	3	4	9.0	6.1
Mayai	Local check	4	4	11.0	11.5
Mean				8.9	4.3
LSD _{0.05}					3.1

Vigourness: 1= Very poor; 5= Very vigour

successful programs in South Africa, Zambia and Uganda. The sweetpotato breeding and evaluation program in South Africa has been very effective. In South Africa 21 improved cultivars and lines, of which 14 were developed in South Africa, were found to be acceptable to resource-poor farmers and recommended for on-farm testing (Laurie *et al.*, 2003). In Uganda, variety Ejumula (a local landrace) and SPK 004 (an improved variety with an origin in Kenya) have widely been accepted by farmers and processors for their high yields and dry matter contents (Mwanga *et al.*, 2003b).

For this particular study all varieties selected for high root yields, dry matter contents plus consumer acceptance have

been advanced in adaptability studies under diverse agro-ecologies. In these sites multiplication at primary sites have been initiated for the continuous supply of clean healthy planting materials.

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Table 4: Yield performance and dry matter contents of orange-fleshed sweet potato varieties at Kibaha and Hombolo sites, Tanzania (2002-2003).

Variety	CIP number	Root yield (t/ha)						Dry matter content (%)	
		Kibaha			Hombolo			Kibaha (2002)	Hombolo (2003)
		S	L	Total	S	L	Total		
Tainung 64	440189	1.0	7.7	8.7	0.6	2.0	2.6	27.3	35.3*
Jonathan	420014	1.0	10.0	11.0	0.2	1.1	1.3	30.6*	30.7*
Salyboro	187017-1	2.7	11.7	14.4**	1.8	4.0	5.8**	30.7*	30.7*
Centenial	440112	2.0	9.3	11.3**	0.1	0.5	0.6	30.6*	30.6*
W-123	440018	-	-	-	0.1	0.5	0.6	40.8*	40.2*
W-151	440005	3.3	12.0	15.3**	-	-	-	-	-
Zapallo	420027	2.0	11.0	13.0**	0.6	1.9	2.5	25.6	25.7
Jewel 31	440031	2.7	10.7	13.4**	0.8	1.0	1.8	30.5*	30.6*
VSP-4	440228	2.7	13.0	15.7**	0.3	1.6	1.9	28.7	28.6
Nemanete	-	2.0	6.0	8.0	0.4	0.8	1.2	37.5*	37.5*
Kandee	440140	4.7	4.3	9.0	0.6	1.1	1.7	30.7*	28.2
CN 317	440090	5.0	6.7	11.7**	0.3	0.7	1.0	28.2	30.7*
Tainung 65	440215	3.0	15.3	18.3**	0.8	7.8	8.6**	22.8	28.2
VSP-3	440287	3.0	12.3	15.3**	0.3	2.7	3.0**	28.0	28.2
TIB	440060	2.3	6.0	8.3	0.4	2.3	2.7**	30.6*	30.6*
Jewel 38	56638	1.0	4.0	5.0	1.0	2.3	3.3**	23.4	23.6
Resisto	440001	4.0	1.0	5.0	0.5	2.6	3.1**	27.5	27.5
Excel	440016	1.0	7.7	8.7	0.6	3.9	4.5**	42.2*	21.0
Japan Tresmesino	420009	1.7	14.0	15.7**	0.3	3.3	3.6**	27.6	27.5
Julian	440141	2.3	2.7	5.0	-	-	-	36.3*	-
Carrot-C	Local check	1.7	9.0	10.7	-	-	-	34.5*	-
Mayai	Local check	1.3	11.0	12.3*	0.6	0.9	1.5	36.6*	37.9*
Mean		2.4	8.80	11.2	0.5	2.1	2.6	31.0	
CV (%)					28.4	61.6			
LSD _{0.05}					1.0	1.9			

S- Small, L-Large * Selected for high dry matter contents** Selected for high yields.

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Table 5: Farmers assessment of cooked roots of OFSP varieties tested at Kibaha station, Tanzania (2002/03)

Variety	Scores				
	Appearance	Taste	Mealyness	Fibrousness	Overall acceptability
Excel	2.9	3	2.8	4.5	3.2
Jonathan *	3.4	3.3	2.7	3.7	3.7
Jewel *	3.4	3.4	2.8	3.8	3.7
Zapallo*	2.7	3.7	3.1	3.6	3.4
Centenial	3.3	3.4	2.8	3.5	3.2
VSP-4	3.1	2	2	3	2.4
Japon Tresmesino	2.5	3.1	2.5	3.2	3.2
Jewel 38	3.1	2.9	2.5	3.2	2.9
TIB*	2.9	3.3	3.2	3.3	3.3
CN 317	3	2.9	2.8	3.2	3.1
Kandee *	2.6	3.3	4.3	3.7	3.5
Nemanete*	2.9	3.4	3.1	3.7	3.3
Salyboro	2.4	2.2	1.9	2.6	2.3
Tainung 64	3.4	3	2.8	3.1	3.1
VSP 3	2.8	2.3	2	3.3	2.3
Resisto	3	3.4	2.8	3.3	3.1
W-151 *	3.6	3.7	3.4	3.5	3.6
Julian	3.4	2.8	2.5	3.3	3
Tainung 65*	3	3.4	3.3	3.8	3.5
Carrot-C (local)*	3.7	4.5	4.4	4.4	4.4
Mayai*	2.9	2.7	3.2	3.5	3.3

N= 26; Scores: 1= Very bad, 2= Bad, 3= Moderate, 4= Good, 5= Very good

*Selected varieties for further adaptability studies and on-farm evaluation and promotion

Table 6: Farmers' assessment of cooked roots of OFSP varieties tested at Hombolo Station, Central Tanzania (2002/3).

Variety	Scores				
	Appearance	Taste	Mealyness	Fibrousness	Overall acceptability
Excel	3.7	2.9	1.9	2.9	2.8
Jonathan*	3.9	3.9	3.1	4.3	3.8
Jewel	3.3	3.7	2.7	3	3
Zapallo *	3.9	3.7	3.1	4.4	3.6
Centenial*	3.9	3.8	3	3.8	3.8
VSP-4	3.6	3.1	2.8	3.7	3
Japon Tresmesino*	3.6	3.8	2.9	3.7	3.8
W-123*	3	3.4	2.7	3.9	3.3
Jewel 38	3.7	3.2	2.6	3.1	3
TIB*	3.5	3.8	3.1	3.2	3.3
CN 317	3.4	3.2	2.7	3.3	3.2
Kandee*	4.1	3.9	3.1	3.6	3.8
Nemanete	2.8	3.1	3.3	3.4	2.8
Salyboro	3.2	3.4	3.3	3.8	3.2
Tainung 64*	3.7	4	2.6	3.3	3.5
VSP 3*	4	4.1	3.2	4	3.9
Resisto	3.2	3.2	2.8	3.2	3
Tainung 65*	4.2	4.2	3.4	4.4	4.1
Mayai*	2.8	3.4	3.4	3.3	3.3

N= 30; Scores: 1 = Very bad, 2 = Bad, 3 = Moderate, 4 = Good, 5 = Very Good

*Selected varieties for further adaptability studies and on-farm evaluation and promotion

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Genotypic variation among sweetpotato clones for β -carotene and sugar content

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Abstract. An F1 population of parents and half-sibs was replicated in field plantings to generate roots to assess levels of β -carotene, sucrose, maltose, and fructose. DNA was also extracted from each genotype and used to generate AFLP molecular markers. The intent was to identify trait-linked AFLP molecular markers. Genotypes were grouped into phenotypic classes based on their standard deviations from the mean. Association parameters between three classes of each respective sugar and molecular marker profiles were made. Discriminant analysis was found to be a useful tool in building progeny selection models in breeding trials.

Introduction

The importance of the nutritive value of the sweetpotato as human food and animal feed has been well documented by Woolfe (1992). Rubatzky and Yamaguchi (1997) state that as a food, the roots may be roasted, baked, fried or prepared in various combination dishes, providing a rich source of carbohydrates and Pro-vitamin A. Pro-vitamin A or β -carotene and sugar content have been found to be important consumer traits for various markets (Woolfe, 1992).

Recent studies on root sugar and β -carotene content have focused on physiological assessment and little on breeding strategies (Bushway, 1986; Picha, 1987; Lu and Sheng, 1990; Katayama *et al.*, 1996; K'Osambo *et al.*, 1998 and Labonte *et al.*, 2000). According to Picha (1987) carbohydrates constitute most of the dry

matter in sweetpotatoes and these carbohydrates exist in the form of starch and sugars. Sucrose, glucose and fructose are the main sugars in raw sweetpotatoes and sweeter baked sweetpotatoes are usually more acceptable to consumers. Picha (1985) also developed reliable HPLC procedures for quantitative analysis of sugars in raw and baked sweetpotatoes. Other methods that have been used for sugar determination include refractive index (Walter, 1992) and near infrared transmittance (Lu and Sheng, 1990; Katayama *et al.*, 1996). Bushway (1986) and Simonne *et al.* (1993) have used HPLC for determination of β -carotene content. However this methodology is tedious and Takahata *et al.* (1993) have documented a quicker method that links β -carotene content and the intensity of the orange flesh color of the sweetpotato. β -carotene has been associated with prevention of night blindness in children and orange fleshed sweetpotato cultivars being low input crops are therefore attractive sources for β -carotene for low income societies.

Most of the breeding programmes for cultivars with high β -carotene have used a classical approach of mass selection. Cultivars that have been developed using this method include 'Jewel' and 'Beauregard'. However, genetic advance in breeding sweetpotatoes with desirable traits is slow and resource consuming.

Hall and Phatak (1993) have reported that the low success in interspecific crosses has precluded the use of genetically related species in sweetpotato improvement. The

hexaploid, self-incompatibility and heterozygous nature of the sweetpotato make inheritance studies very complicated. This genetic condition greatly affects breeding and selection for quantitative traits by slowing down progress in genetic advance within sweetpotato breeding programmes. However the high level of heterozygosity and wide diversity in the germplasm of cultivated sweetpotatoes have also been valuable sources of favorable genes for traits that need to be incorporated through appropriately designed breeding and selection methodologies. Jones (1965, 1986) has proposed breeding methods for many quantitative traits; however, reports on breeding methods that incorporate molecular marker approaches for organoleptic traits are uncommon. Such molecular techniques that would affect interspecific gene transfer could greatly improve quantitative breeding programs (Hall and Phatak, 1993).

Molecular marker assisted selection in sweetpotatoes began with the use of bulked segregant analysis (BSA) (Michelmore *et al.*, 1991) by Ukoskit *et al.* (1997). In their study, Ukoskit *et al.* (1997) identified a primer that could be used to detect linkage between DNA markers and the root-knot nematode resistance gene. The biggest drawback of BSA is the need for new DNA bulks from a homozygous pure F₂ population for every loci targeted. In addition we are not assured of detecting differences between bulks. These hurdles spurred us on to seek alternative approaches to marker assisted selection for sweetpotato improvement. One such approach is the use of a multivariate statistical technique, namely discriminant analysis to associate molecular markers with quantitative traits. Due to the sparsely saturated genome maps in sweetpotato, we seek to develop a method that does not require *a priori* genetic maps and also one that is capable of analyzing multiple traits or variables simultaneously. The multiple variables or molecular markers in our case were generated by AFLP. Discriminant analysis (DA) is a multivariate statistical technique that can identify

differences among groups of individuals (or treatments) and improve the understanding of relationships among the variables measured within those groups (Cruz-Castillo *et al.*, 1994). DA determines how best to separate or discriminate two or more groups of individuals, given quantitative measurements of several individuals, through simultaneous analysis of several variables (Rencher, 1992). DA finds linear functions of variables that maximally separate two or more groups of individuals while keeping variation within groups as small as possible. DA may be used when it is important to separate known groups or *a priori* groupings, and to identify major sources of difference between groups. Such groups may be determined through a statistical procedure like molecular marker profiling or through cluster analysis techniques. The discriminant analysis will therefore provide information on the discriminatory power of each variable or marker thus determining whether a particular set of variables or markers is useful in separating previously delineated groups (Rojas *et al.*, 2000). We propose to use AFLP and discriminant analyses in a marker-trait association study with the main objective of identifying trait-linked AFLP molecular markers for sugar and β -carotene content.

Materials and Methods

Planting material. An F₁ population of parents and half-sibs that consisted of 45 clones was used as source material. Maternal parental clones used to obtain the open pollinated F₁ half-sibs were 'Beauregard', 'Excel', '94-96', '86-110', '86-33' and '96-117'. F₁ 'Beauregard' progeny were coded as 'BX' while 'Excel' F₁ progeny were coded as 'EL'. The rest of the F₁ progeny were given the codes '96', '110', '33' and '117' to reflect parentage. Field trials were conducted during summer at the Sweetpotato Research Station (Chase), Louisiana in 2001. Each experiment was laid out as a randomized complete block trial with 3 blocks. Each plot consisted of 5 plants with an inter-row spacing of 60cm and

within row spacing of 30cm. Field management followed commercial sweetpotato cultural practices recommended by Boudreaux (1994). The crop was harvested after four months and four to five roots from all the plants in a plot were combined for post-harvest laboratory analysis. The roots were cured at 29°C and 90 to 98% relative humidity for about 10 days. Thereafter the roots were stored at 15°C and 90% relative humidity.

DNA analysis. DNA extraction and DNA analysis using AFLP were done as described by (Mcharo et al, 2003). Young leaves were harvested and stored at -40°C until needed. Total DNA was isolated from 100mg of fresh leaf tissue using the Genelute plant genome kit (Sigma-Aldrich Inc., St. Louis, Mo). The DNA samples were amplified in a three step process using a GeneAmp PCR system 9600 thermocycler (Perkin Elmer, Fulerton, CA) using techniques adapted from Vos et al (1995). Four primer pairs were used for selective amplification.

Sugar and β -carotene analyses. Analyses of sugar and β -carotene content were done on raw roots stored for 4 to 10 weeks after curing, during which sugar content changes were minimal (Picha, 1987). Sugar content was assayed as described by Picha (1987). Unpeeled roots were halved longitudinally and uniformly grated over the entire surface to a depth of about 3 mm. The grated tissue from each of the 4 roots per replication was combined and 10.0g was homogenized in 80% ethanol for 1 min at high speed using a Brinkman homogenizer (Brinkman Instruments, Westbury, NY). The resulting slurry was immediately boiled for 15 min, cooled, and filtered through Whatman #4 paper. The residue and original container were washed with additional 80% ethanol and the filtrate was made to a final volume of 100ml. Sugar content of the filtrate was determined by high performance liquid chromatography (HPLC) as described by Picha (1985).

Hunter color values (Hunter, 1958) measurements were taken on the flesh of representative cured roots from each plot using a Minolta spectrophotometer cm 3500d (Minolta Co., Osaka, Japan). This color system is based on *L*, *a* and *b* measurements where *L*=lightness, *a*=green-red scale, *b*=blue-yellow scale and intensity. This method measures color by using a positive and negative number scale. For the color value *a*, a positive value is perceived as red, a negative value as green. For the color value *b*, a positive value is perceived as yellow, a negative value as blue. Lightness (*L*) is measured on a scale of 0-100 where 0 = black and 100 = white. Flesh color measurements were taken by measuring the cross-section of the interior of the root.

Statistical analysis. Step discriminant analysis using the STEPDISC procedure (SAS, 2001) was used to select the most informative markers from the original set of markers. The forward selection options in STEPDISC was used to select markers to be included in the classification model. A stop level for the number of markers desired to achieve at least 85% prediction accuracy was imposed to choose the most discriminating markers (SAS, 1999). Wilk's lambda was used as the criterion to determine the classification efficiency with the entry of each marker. The selected markers were then used in a discriminant analysis, DISCRIM option (SAS, 2001), to develop and validate a phenotypic group prediction model and to predict group membership of the test genotypes. The categorical nature of the data could not allow assumption of normal distribution to be made hence a non-parametric method; the k-nearest neighbor method (Rosenblatt, 1956) was used to estimate the group specific densities that produce a classification criterion. The performance of the discriminant criterion was evaluated by group specific error count estimates during cross-validation. This estimator gives the proportion of misclassified observations in each group.

Results and Discussion

Sugar content. Table 1 outlines the sugar content of the various clones studied. Phenotypic grouping of the clones for all sugars was based on the number of standard deviations from the mean. Group 1 contained clones that were equal to or less than negative two standard deviations from the mean. Clones in group 2 were within negative one and positive one standard deviation from the mean while group 3 had consisted of clones at positive two standard deviations or greater. Fructose content ranged from 3.58 ug/20ul of solution in the clone 110-1 to 18.35ug/20ul of solution in BX-8. The same clones had the lowest and highest glucose contents respectively with 110-1 having 6.41ug/20ul and BX-8 containing 30.03 ug/20ul. Clone 110-11 recorded the highest sucrose content at 60.13ug/20ul however the same clone had low scores for fructose (9.31ug/20ul) and glucose (13.31ug/20ul). Labonte *et al.* (2000) observed similar sugar content trends in other cultivars. Clone 110-1 had a very high sucrose content while clone BX-8 contained low levels of sucrose. The lowest sucrose content was recorded in clone 117-9 (17.19ug/20ul).

β -carotene content. Investigations by Takahata *et al.* (1993), Ameny and Wilson (1997) and Hagenimana *et al.* (1998) revealed negligible levels of β -carotene in non-orange cultivars. Takahata *et al.* (1993) studied the relationship between β -carotene content and Hunter color values in sweetpotato cultivars. They found that color value a^* had the highest correlation coefficient (0.891) with β -carotene and concluded that the color value a^* could be used in rapidly estimating the β -carotene content in breeding programs. The results for the Hunter color value a^* are presented in Table 2. The phenotypic grouping was based on the clear demarcation between white, cream-yellow and orange flesh color of clones from visual observation and as represented by the Hunter color value a^* . Group1 clones had a white flesh color; group 2 clones had various shades of cream-yellow flesh color

while group 3 clones were orange. Clone 96-9 had the lowest a^* value (-0.10) and a concomitant high L^* value (data not shown). This clone had a white flesh color and was not expected to contain any determinable β -carotene quantities. Clone 117-7 had a deep orange color and recorded the highest a^* value (36.80); however it's L^* value was not as high as that of 96-6. A high L^* value indicates an increasing lightness in the color hence a lower level of β -carotene content.

Discriminant analysis. Discriminant analysis (Table 3) elucidated informative markers that could be used for classification of a genotype of unknown grouping. The numerical value for each marker name indicates its molecular weight in base pairs. We noted that markers *cag60* and *cag203* were important in describing variation for both fructose and glucose. However the same markers were not important in explaining variation for sucrose. Discriminant analysis selected marker *cag253* (Table 3) as the most informative in describing variation for β -carotene content within the samples studied. Table 3 also shows the total number of markers selected to build a predictive model for genotype classification purposes. The objective of selecting the markers was to build models that contained as few markers as possible without compromising on their phenotypic group prediction accuracy. When tested by cross-validation the models achieved a prediction accuracy of at least 85% for fructose and 92% for glucose. β -carotene needed fewer markers for the discriminant model than the sugars.

Conclusion

Our results indicate the possibility of using molecular markers to predict phenotypic grouping of new genotypes of unknown nutrient composition. We found promising results through the use of the discriminant analysis technique for quick selection during the early stages of sweetpotato breeding. A second year of data is currently being

Table 1: Fructose, glucose and sucrose content and resultant phenotypic classification of sweetpotato clones from an F₁ polycross of 'Beauregard', 'Excel', '94-96', '86-33', '86-33' and '96-117'.

Clone name	Fructose		Glucose		Sucrose	
	mg/g	Group	mg/g	Group	mg/g	Group
110-1	2.0	1	3.0	1	29.5	3
110-11	4.5	2	6.5	2	30.0	3
110-12	3.5	2	5.5	1	16.5	2
110-4	4.5	2	6.5	2	16.0	2
110-5	8.0	3	12.0	2	19.5	2
110-6	2.5	1	4.5	1	21.5	2
110-9	8.0	3	13.5	3	14.5	2
117-1	3.5	2	7.0	2	24.5	2
117-10	5.0	2	10.0	2	16.0	2
117-3	8.5	3	15.5	3	17.5	2
117-5	2.0	1	3.5	1	17.5	2
117-6	4.5	2	10.0	2	16.0	2
117-7	4.0	2	7.5	2	19.5	2
117-8	4.5	2	9.5	2	17.0	2
117-9	8.5	3	14.5	3	8.5	1
117p	4.5	2	7.5	2	22.0	2
33-1	7.0	2	12.0	2	18.0	2
33-10	4.0	2	6.5	2	27.5	3
33-11	3.0	1	5.0	1	23.5	2
33-3	9.5	3	15.0	3	20.0	2
33-7	6.0	2	10.5	2	16.0	2
33-8	8.5	3	14.6	3	23.0	2
33-9	8.5	3	13.5	3	17.5	2
96-10	5.0	2	11.5	2	29.5	3
96-11	5.5	2	7.5	2	30.0	3
96-2	3.5	2	6.5	2	23.5	2
96-4	5.5	2	10.5	2	25.5	3
96-5	4.0	2	7.5	2	22.0	2
96-7	7.0	2	12.5	2	23.5	2
96-8	2.0	1	3.5	1	27.5	3
96-9	5.5	2	10.0	2	11.0	1
96p	7.0	2	11.0	2	23.0	2
BX-1	8.5	3	13.5	3	10.0	1
BX-16	7.0	2	12.0	2	21.0	2
BX-2	7.0	2	11.0	2	16.5	2
BX-21	3.0	1	5.0	1	15.5	2
BX-5	7.0	2	11.0	2	22.5	2
BX-6	6.5	2	11.5	2	15.0	2
BX-8	9.0	3	15.0	3	12.5	1
BXp	7.0	2	12.0	2	11.5	1
EL-11	6.5	2	15.5	3	16.0	2
EL-4	2.5	1	4.5	1	14.5	3
EL-5	7.5	2	15.0	3	9.5	1
EL-7	9.0	3	13.5	3	16.0	2
EL-8	3.5	1	6.0	1	20.5	2

Clones followed by the letter 'p' are parental clones.

Table 2: Hunter color value a* and phenotypic classification for β -carotene content of sweetpotato clones from an F₁ polycross of 'Beauregard', 'Excel', '94-96', '86-33', '86-33' and '96-117'.

Clone name	Color value a*	Phenotypic group
110-1	29.47	3
110-11	31.79	3
110-12	15.63	2
110-4	30.92	3
110-5	31.22	3
110-6	30.46	3
110-9	24.45	3
117p	36.51	3
117-1	33.47	3
117-10	32.21	3
117-3	30.50	3
117-5	33.77	3
117-6	28.73	3
117-7	36.80	3
117-8	18.96	2
117-9	2.13	1
33-1	21.57	3
33-10	3.19	1
33-3	33.48	3
33-7	28.01	3
33-8	25.84	3
96-10	2.27	1
96-11	30.25	3
96-2	9.67	1
96-4	22.83	3
96-7	17.45	2
96-8	31.46	3
96-9	-0.10	1
96p	31.40	3
BX-1	5.00	1
BX-16	13.43	2
BX-2	24.20	3
BX-5	31.18	3
BX-8	33.96	3
BXp	27.99	3
EL-11	11.92	1
EL-4	33.09	3
EL-5	0.89	1
EL-7	30.63	3
EL-8	14.90	2

Clones followed by the letter 'p' are parental clones.

Table 3: Four most informative markers for sugar content and β -carotene in sweetpotato.

Trait		Total markers selected	4 most important markers selected	Wilk's Lambda	Pr < Lambda
Sugars	Fructose	14	cag203	0.72	0.0023
			cag60	0.50	<0.0001
			cag95	0.35	<0.0001
			cag147	0.28	<0.0001
	Glucose	13	cag240	0.74	0.004
			cag203	0.57	0.0004
			cag60	0.43	<0.0001
			cag192	0.33	<0.0001
	Sucrose	11	cag206	0.71	0.0018
			cag122	0.52	<0.0001
			cag91	0.37	<0.0001
			cag119	0.27	<0.0001
β -carotene		10	cag253	0.68	0.0007
			cag91	0.52	<0.0001
			cag94	0.40	<0.0001
			cag242	0.31	<0.0001

Table 4: Error count estimates from cross-validation using nearest neighbor for various traits in sweetpotato.

	Phenotypic group			Total
	1	2	3	
Fructose	0.33	0.12	0.00	0.15
Glucose	0.14	0.09	0.00	0.08
Sucrose	0.17	0.00	0.13	0.10
β -carotene	0.12	0.20	0.04	0.12

analyzed to more fully document our preliminary findings.

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Advances in yam (*Dioscorea* spp.) genetics and genomics

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Abstract. Yams (*Dioscorea* spp.) constitute a staple food crop for over 100 million people in the humid and subhumid tropics. They constitute a multi-species, polyploid crop that is vegetatively propagated. *Dioscorea rotundata* and *D. cayenensis* (known as white and yellow Guinea yams, respectively) are the most important yams in West and Central Africa where they are indigenous, while *D. alata* (referred to as water yam) is the most widely distributed species globally. The genetics of yams is least understood among the major staple food crops due to several biological constraints and research neglect. Research to unravel the apparent complexity of the yam genome will have far-reaching implications for genetic improvement of this important tuber crop. Some progress has been made in recent years in germplasm characterization and the development of molecular markers for genome analysis. Genetic linkage maps based on amplified fragment length polymorphism (AFLP) markers have been constructed for *D. rotundata* and *D. alata*. These linkage maps were used to scan the genome for quantitative trait loci (QTL) associated with genes conferring resistance to *Yam Mosaic Virus* (YMV) in *D. rotundata* and anthracnose (*Colletotrichum gloeosporioides*) in *D. alata*. In addition, candidate random amplified polymorphic DNA (RAPD) markers associated with major genes controlling resistance to YMV and anthracnose have been identified that could be used for selection and pyramiding of YMV and anthracnose resistance genes in yam improvement. Also, molecular markers such as RAPDs, AFLPs, and microsatellites or simple sequence repeats (SSRs) have been developed for yam genome analysis. An initial c-DNA library has been constructed in order to develop expressed sequence tags (ESTs) for gene discovery and sources of additional molecular markers. This paper will review the advances made, discuss the implications for yam genetic improvement and germplasm conservation, and outline the direction for future research.

A review of post-harvest activities for cassava in Tanzania

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Abstract. Post-harvest problems affecting cassava in Tanzania are high losses during marketing of fresh cassava and rudimentary processing technology. A needs assessment study identified reduction in income from post harvest losses as a major problem facing stakeholders involved in production and marketing of fresh cassava roots from rural areas to urban markets. The most suitable intervention identified to address the problem of fresh cassava root storage was adoption of the modified low-cost fresh cassava root storage technology originally developed by the Centro Internacional de Agricultura Tropical (CIAT) in Columbia and Natural Resources Institute (NRI) of U.K. The technology was tested in several villages in Coast region and two urban markets in Dar es Salaam, after which a flexible dissemination strategy was developed and applied to other villages between 1996 and 1998. Processing of cassava and other root crops into more

storable forms offers an opportunity to overcome perishability of the fresh produce. Processing of cassava also provides a means of adding value to the crop. Cassava processing methods in Tanzania are varied especially in the four main cassava growing zones. The products obtained are always moulded, contaminated with sand and may contain high levels of cyanogens. This is because cassava processing methods are simple and do not result in tissue disintegration but leaves behind high levels of cyanogens in intact peeled whole or split roots. The most suitable processing method adopted in these zones since 1996 is chipping or grating of fresh cassava roots before obtaining flour. The flour is an intermediate product for various bakery, industrial and pharmaceutical products. Efforts to disseminate the technology were initiated and some villages in eastern and lake zones were involved.

Characteristics and control of a new basidiomycetous root rot of cassava (*Manihot esculenta*) in Ghana

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Abstract. Cassava (*Manihot esculenta*) is one of the most important food crops in the tropical world. Diseases such as African cassava mosaic virus (ACMV), cassava bacterial blight (CBB) and cassava anthracnose (CAD) constitute a major constraint to cassava production in parts of sub-saharan Africa. A mushroom type of fungus previously known to be parasitic on forest tree species has in recent years been found attacking cassava and causing high yield losses in some of the major cassava growing districts in Ghana. Surveys have established presence of the disease in the Volta, Central and Ashanti regions of the country. Major symptoms of the disease include wilting and defoliation and eventually plant death. Storage roots of infected cassava plants are often rotten and result in yield

losses as high as 100%. Local and improved genotypes of cassava available to farmers in endemic areas are susceptible to attacks by this fungus. The large, bright yellow fruiting body produced by the fungus is characteristic of the basidiomycete *Polyporus sulphureus* (*Laetiporus sulphureus*). Citrus and a number of important timber tree species are also hosts of this fungus. Results from field screening of cassava genotypes indicate that materials with high levels of resistance to this fungus are available.

Effect of different storage methods on the shelf-life of fresh sweetpotatoes in Gairo, Tanzania

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Abstract. One of the major constraints to the potential of sweetpotatoes is its perishability commencing soon after harvesting. This is worsened by the lack of suitable storage methods as well as the difficulties to store improved varieties such as SPNO. This study was therefore intended to evaluate the storability of improved sweetpotato varieties and assess the effectiveness of selected storage methods under Tanzanian conditions. Four storage methods were investigated with 50kg of fresh injury free SPNO sweetpotato tubers. The storage methods covered under this study included traditional pit, improved open pit, improved housed pit (*mjinge*) and raised woven structure (*kihenge*). Results obtained from this study showed that housed pit storage (*mjinge*) performed comparatively well whereas the traditional method was the poorest in all attributes. For example, sugar content of sweetpotato stored using *mjinge* method increased significantly ($P < 0.05$) from

6.25% to 9.25%. Although *kihenge* method performed well with respect to crude protein that increased from 4.90% to 6.06%, its performance in other attributes was poor. In addition, sweetpotatoes stored by *mjinge* method had good quality attributes of sweetness, starchy mouth feel, smell, colour and general acceptability, scoring between 3.37 and 4.19 in the hedonic scale (0- 5). Sweetpotato stored using this method could be processed for blending with cereals to make composite flours for porridge and also for making fried snacks. Efforts to tap the vast potential of sweetpotatoes are now underway through joint dissemination with the stakeholders.

Potential of cassava and sweetpotato leaves to contribute to the Vitamin A requirements

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Abstract. Cooked green leafy vegetables constitute a regular relish in most households of Tanzania, usually served as a side dish for the starchy based staples. Provitamin A carotenoids from these vegetables are major dietary sources of vitamin A in Tanzania. Cassava and sweetpotato are widely grown in Tanzania including the semi-arid areas due to their tolerance to harsh weather conditions. Besides caloric density provided by these tubers to the diet, their leaves also contribute to the vitamin A requirements of populations in production areas. In this study five sundried green leafy vegetables including leaves of cassava and sweetpotato were cooked without oil, with sunflower oil or with red palm oil. The total amount and *in vitro* accessibility of α -carotene and β -carotene from a portion (100g) of vegetable relish was determined. The *in vitro* method used simulated the digestion process in the gastrointestinal tract. Carotenoids released after digestion were quantified using high performance liquid chromatography. The total amount of β -carotene varied between 1211 and 3659 mg/100g among the five vegetable sources studied. From green leaves cooked without oil, 8-29% of the β -carotene content became accessible after *in vitro* digestion and 39-94% from leaves cooked with sunflower or red palm oil. Adding red palm oil instead of sunflower oil resulted in about twice as much accessible β -carotene, due to high accessibility of its β -carotene content. The red palm oil contributed also a considerable amount of α -carotene. The results showed

that by eating vegetable relishes with added oil daily, it should be possible to provide the recommended intake amount of vitamin A.

Introduction

Plants and animals are two major dietary sources of vitamin A in humans. Vitamin A from animal sources is in a preformed form and therefore readily available for utilization whereas that from plant sources is in the form of provitamin A carotenoids which have to be converted to the active form of vitamin A (retinol) and its derivatives in the gut before being utilized (Booth *et al.*, 1992). This implies that, of the two major dietary sources of vitamin A, animal sources would be most preferred in terms of efficacy of vitamin A supply to humans. However, in most developing countries animal sources of vitamin A are scarce, expensive and beyond the reach of the majority due to socio-economic constraints. Thus provitamin A carotenoids from vegetables and fruits remain the major dietary source of vitamin A in these countries. In Tanzania various types of leafy vegetables including sweetpotato (*Ipomoea batatas*) and cassava (*Manihot esculenta*), are widely consumed and constitute a regular relish in many rural households.

Increased consumption of carotene rich vegetables and fruits has for a long time been recommended as the most appropriate and sustainable solution for improving vitamin A status of populations in low-income countries due to their high carotene contents. However,

it is now known that the ability of provitamin A carotenoids from leafy vegetables to improve vitamin A status is limited by their low bioavailability (de Pee *et al.*, 1995 and 1998; Castenmiller *et al.*, 1999). Bioavailability is defined as the efficiency with which provitamin A carotenoids are absorbed and converted into vitamin A in the body. Thus to maximize the benefit of provitamin A containing foods, strategies to increase the dietary intake of these foods should also include measures to enhance carotenoid bioavailability.

This paper discusses some processing and preparation methods, which have been found to enhance the bioavailability of provitamin A carotenoids from plant sources. Results from our research study on the *in vitro* accessibility of carotenes in leafy vegetables cooked without and with sunflower or red palm oil and their estimated contribution to the vitamin A requirements support available information.

The objective of our study was to determine α -carotene and β -carotene content and the *in vitro* accessibility in five types of green leafy vegetables commonly used in Tanzania and cooked with either sunflower or red palm oil.

Materials and Methods

The study emulated the traditional method of vegetable processing commonly practiced in semi-arid areas of central Tanzania. It involves sun drying of fresh vegetables, a method commonly used to preserve vegetables for off-season consumption. The dry vegetables were cooked into a vegetable relish using a traditional recipe without and with oil (red palm oil or sunflower oil). Cooked vegetable relish samples were analyzed for the bioaccessibility (amount released from the vegetables after digestion and available for absorption in the gut) of their carotenes using an *in vitro* digestion method. The contribution of one portion of vegetable relish to the recommended daily intake (RDI) was obtained by calculation.

Five different types of freshly harvested green leafy vegetables were purchased from markets in Dar es Salaam. They included the leaves of amaranth (*Amaranthus* spp), cow pea (*Vigna* spp), sweetpotato (*Ipomoea batatas*), pumpkin (*Cucurbita moschata*) and cassava (*Manihot esculenta*).

The sunflower oil (Zeta) used was purchased in a supermarket and the red palm oil (Carotino, Malaysia) was taken from a large stock, which was to be used in a dietary intervention study with pregnant women in Tanzania (Lietz *et al.*, 2000).

Sample preparation. After blanching in boiling water for 2-3 minutes, all the leaves were sundried in open sunlight. A portion of fresh leaves from each vegetable were blanched and then kept frozen as a reference sample. Samples were transported under cold conditions and kept in a freezer (-20 °C) before analysis. The reference sample was freeze-dried before determination of total content of α - and β -carotene.

Each type of the sundried leaves was divided into three equal portions (~10g dry weight) and cooked in the laboratory according to the traditional recipe. The leaves were soaked in tap water (1:9) for about 5 min and cooked with a small amount (~1g) of table salt for 15 min. In two of the samples sunflower oil or red palm oil was added at the end of the cooking time. The ratio of sundried vegetable leaves to oil was about 1:1, on a dry weight basis. Caution was taken to avoid excessive boiling after addition of oil. Cooked samples were kept frozen at -20 °C and later freeze-dried before analysis. For comparison of results one portion of vegetable relish was standardised to 100 g, which included 10 g of sundried green leaves, water and no oil or 10 g of sunflower oil or red palm oil.

Determination of oil content in prepared vegetable relish. The oil content in the vegetables cooked with either sunflower oil or red palm oil was determined by using Soxhlet extraction (AOAC 963.15) AOAC, 1990). Extraction was performed with

petroleum ether (B.P. 40-60°C) (Merck, Darmstadt, Germany).

Determination of carotene content in vegetables. Carotenoid extractions were carried out according to a method described by Pettersson and Jonsson (1990). High Performance Liquid Chromatography (HPLC) grade solvents of methyl-t-butyl ether, methanol, acetone and petroleum ether (B.P. 40-60°C) (Merck) were used. Other chemicals used were 95% ethanol (Kemetyl AB, Stockholm, Sweden) and analytical grade sodium chloride (Merck).

The freeze-dried vegetable relish was ground in a blender for about 30 seconds. About 0.5 g of the finely ground sample (in duplicate) was accurately weighed into a flask, reconstituted with 10 ml of distilled water and allowed to stand for 5-10 min. In one of the duplicates 100 µl of an internal standard (200 µg trans-β-apo-8-carotenal/ml) (Sigma Chemicals A-9956, St Louise, MO, USA) was added. The extraction was repeatedly carried out by moderate shaking for 5 min with equal amounts (20 ml) of acetone and ethanol containing 0.1 % (w/v) butylated hydroxytoluene (BHT) (Sigma Chemicals), until the residue was colourless. The extracts were decanted into a separatory funnel containing 20 ml of petroleum ether and 20 ml of 25 % (w/v) NaCl solution. After transferring the carotenes to petroleum ether by gently swirling the separatory funnel, the lower layer was drawn off and washed repeatedly with 20 ml of petroleum ether until the extract was colourless. The pooled extracts were evaporated under nitrogen in a rotary vacuum evaporator at 35 °C. The residue was dissolved in 10 µl of mobile phase solvent and filtered through a 0.45 µm pore size cellulose membrane filter (Sartorius Filtration AB, Sundbyberg, Sweden) before HPLC analysis.

Due to the risk of oxidation and formation of isomers during sample preparation, the extraction was performed at dimmed light and room temperature.

Determination of in vitro accessibility of carotenes. The in vitro digestion procedure developed by Hedrén *et al.* (2002), which simulates digestion in the gastrointestinal tract, was used to determine the bioaccessibility of carotenes in the vegetable relishes. Briefly, the freeze-dried vegetable relish was homogenized and reconstituted with distilled water. Digestion was carried out by acidifying the sample (pH 2), followed by treatment with porcine pepsin solution and incubation at 37°C in a shaking water bath for one hour. The pH was adjusted to 7.5 and a pancreatin and bile salt solution was added. The sample was further incubated for 30 min. The digesta was centrifuged and the aqueous fraction was extracted with petroleum ether that was evaporated to dryness. The residue was dissolved in 5 or 10 ml of mobile phase solvent and filtered through a 0.45 µm pore size cellulose membrane filter before a reverse phase HPLC analysis.

HPLC determination of provitamin A carotenoids. Trans-β-apo-8-carotenal was employed as internal standard and all-trans-β-carotene (Sigma Chemicals C-9750) was used as an external standard. The concentration of β-carotene standard working solution was confirmed using a spectrophotometer, Hitachi U-1100 (Hitachi Instruments, San Jose, USA), and using the extinction coefficient value for β-carotene in hexane. The provitamin A carotenoids, α- and β- carotene, were determined by isocratic reversed phase HPLC using methyl-t-butyl ether: methanol: water (56:40:4) as mobile phase. The HPLC system comprised a Waters 600 dual piston solvent delivery pump (Waters, Söllerntuna, Sweden) connected to a Waters 996 UV-visible photodiode array detector (Waters) and equipped with a C₃₀ polymeric column (YMC Inc., Wilmington, NC, USA). The C₃₀ ligands are bonded on high silica particles (5 µm) in a stainless steel 250 mm column (4.8 mm i.d.), allowing for phase loading and polarity optimised for

separation of both polar and non-polar carotenoids and their isomers. Millenium 2010 software (Waters) was used to acquire, store and process spectra and chromatographic data. Absorption spectra of the carotenoids were recorded between 250-500 nm at the rate of 0.5 spectra per second and the resolution of 2.4 nm. The flow rate was 1 ml/min and injections were made with a 20 µl loop.

Statistical analyses. Differences in mean values of total β-carotene content in cooked vegetable relishes were tested by analysis of variance (ANOVA). Determination of the significance of differences (p<0.05) among samples cooked without oil, with sunflower oil or red palm oil were obtained by Tukey's HSD multiple rank test.

Results and Discussion

This study has shown that green leafy vegetables studied are good sources of β-carotene with the amount in blanched leaves ranging from 399 to 664 µg/g DM (Table 1). Small proportions of α-carotene amounting to 17±5.2 and 31±2.3 µg /g DM were detected in blanched leaves of amaranth and sweetpotato respectively. Sundrying of vegetables resulted in a wide range of loss of the β-carotene content in the different vegetables (Table 1). However, sweetpotato and cassava leaves retained higher amounts

(62% and 63%) of β-carotene than other vegetables. After sundrying no α-carotene was detected in any of the green leaves. The average amount of total β-carotene from one portion (100g) of the vegetable relishes are shown in Table 2 and varied between 1211 and 3649 µg when cooked without oil. The oil content in the vegetable relishes cooked with either sunflower oil or red palm oil ranged from 47 to 52 %. The total amount of α- and β-carotene in the red palm oil was 107±6.2 and 125±5.2 µg/g oil, respectively.

Of the amount of β-carotene retained, only 8-29 % is available for absorption after cooking without adding oil as measured by an *in vitro* digestion method, which measures the maximum amount of carotenes possible for absorption (Table 3). Adding sunflower oil in the preparation resulted in a manifold increase of the accessibility due to the reasons provided in the section on *in vitro* accessibility of carotene from cooked vegetables ahead. Red palm oil that contains both α- and β-carotene further increased the amount of accessible carotenes to the vegetable relishes when added in the preparation. Calculations made showed that green leafy vegetables cooked without oil may only constitute from 12 to 47% of an individual's daily need of vitamin A, whereas green leaves cooked with either sunflower oil or red palm oil may provide enough daily retinol (Table 4). These findings may have

Table 1: The total amount of A- and β-carotene in green leaves before and after sundrying, (µg/g DM)¹.

Green leaves	Blanched		Blanched and sundried ²	Losses of β-carotene during sundrying ²
	β-carotene	α- carotene		(%)
Amaranth	664±7.8	17±5.2	287±18	57
Cowpea	622±14	Trace	148±1.3	76
Sweet potato	592±9.8	31±2.3	365±7.7	38
Pumpkin	590±21	Trace	121±3.9	79
Cassava	399±15	Trace	250±2.8	37

¹ Mean ± SD in duplicate samples.

² α- carotene was only detected in blanched green leaves.

Table 2: The total α - and β -carotene content in each portion of vegetable relish ($\mu\text{g}/100\text{g}$)¹.

Green leaves	Without oil ²	With sunflower oil ²	With red palm oil	
	(β -carotene)	(β -carotene)	(β -carotene)	(α - carotene)
Amaranth	2851 $\pm$ 17 ^a	2974 $\pm$ 39 ^a	4193 $\pm$ 51 ^b	1491 $\pm$ 73
Cowpea	1475 $\pm$ 13 ^a	1418 $\pm$ 61 ^a	2836 $\pm$ 11 ^b	1196 $\pm$ 5.8
Sweet potato	3659 $\pm$ 106 ^a	4008 $\pm$ 90 ^a	5443 $\pm$ 296 ^b	1480 $\pm$ 76
Pumpkin	1211 $\pm$ 39 ^a	1526 $\pm$ 36 ^b	3067 $\pm$ 17 ^c	1203 $\pm$ 16
Cassava	2233 $\pm$ 71 ^a	2728 $\pm$ 7.0 ^b	4637 $\pm$ 47 ^c	1427 $\pm$ 8.0

¹ Mean $\pm$ SD in duplicate samples. Equivalent to 10 g dry weight of vegetable leaves.

² No α - carotene was detected in relishes cooked without oil or with sunflower oil.

^{abc} Values on the same row not sharing the same superscript were significantly different ($p < 0.05$).

Table 3: The in vitro accessibility of α - and β -carotene in each portion of vegetable relish¹.

Green leaves	without oil ²		with sunflower oil ²		with red palm oil			
	β -carotene		β -carotene		α - carotene		β -carotene	
	(μg)	(%) ³	(μg)	(%) ³	(μg)	(%) ³	(μg)	(%) ³
amaranth	512 $\pm$ 29	18	1724 $\pm$ 137	58	1212 $\pm$ 72	86	2861 $\pm$ 250	68
cowpea	426 $\pm$ 31	29	1267 $\pm$ 73	94	1120 $\pm$ 33	94	2357 $\pm$ 81	83
Sweet potato	316 $\pm$ 37	9	1559 $\pm$ 238	39	1343 $\pm$ 15	90	3240 $\pm$ 246	61
Pumpkin	125 $\pm$ 35	10	969 $\pm$ 146	64	1067 $\pm$ 12	88	2468 $\pm$ 155	81
Cassava	178 $\pm$ 15	8	1284 $\pm$ 29	47	793 $\pm$ 65	56	2340 $\pm$ 201	51

¹ Mean $\pm$ SD in two duplicate samples. Equivalent to 10 g dry weight of the vegetable leaves.

² No α - carotene was detected in relishes cooked without oil or with sunflower oil.

³ Percentage in vitro accessible α - and β -carotene, respectively.

Table 4: The percentage contribution of retinol equivalents (RE) to the recommended safe intake level¹ by one portion of vegetable relish².

Green leaves	Without oil	With sunflower oil	With red palm oil
	(%)	(%)	(%)
Amaranth	47	157	316
Cowpea	39	115	265
Sweet potato	29	143	356
Pumpkin	12	89	273
Cassava	16	116	249

¹ Recommended safe intake level of vitamin A in populations in developing countries, 550 μg RE/day (WHO/UNICEF, 1995)

² Assuming 100 % absorption of the in vitro accessible α - and β -carotene and 25 and 50 % conversion to retinol in mucosa, respectively.

major implications for the design of intervention studies that use a dietary approach to combat vitamin A deficiency in developing countries.

Effect of drying on carotene contents of vegetable. Green leafy vegetables are available throughout the year for most people in Tanzania. However, during dry season in semi-arid areas people mainly rely on leaves dried in open sunlight. Exposure to light and oxygen are known to have an impact on the carotenoids through oxidation and isomerization (Thane & Reddy 1997; Mosha *et al.*, 1997). Maeda and Salunkhe (1981) obtained substantial losses of carotenes (60-94 %) when green leaves of sweetpotato, cassava and cowpea were sundried without blanching. In this study leaves meant for cooking were blanched prior to sundrying, in order to inactivate the enzyme peroxidase and thereby prevent losses of carotenes from degradation to some extent (Negi and Roy, 2000). This resulted in losses between 37 and 79 % of the β -carotene content that is less compared with what was reported by Maeda and Salunkhe (1981). An alternative to drying in open sunlight is the solar drying technology, whereby products are protected from light and therefore retain more carotenes (Maeda and Salunkhe, 1981; Negi and Roy, 2000; Mulokozi *et al.*, 2000).

In vitro estimation of accessible carotenes from cooked vegetables. In evaluating the bioavailability of provitamin A carotenoids in plant foods two important concepts involved are their bioaccessibility and absorption. Bioaccessibility of carotenoids from food sources may be affected by factors such as food matrix, dietary lipids, particle size of the food, protein and low bile secretion. In the case of green leafy vegetables, the leafy matrix seems to be an important factor that affects the bioaccessibility and consequently the bioavailability of carotenes (van het Hof *et al.*, 1998). In green leaves, carotene molecules are organized in pigment-protein complexes located in cell chloroplasts, which

have to be accessed to make the carotenes available. Cooking and reduction of particle size by grinding may reduce the matrix effects and have been reported to have the potential to increase the bioavailability of carotenoids (van het Hof *et al.*, 1998, Castenmiller *et al.*, 1999) possibly by disrupting and softening the plant cell walls and carotenoid protein complexes. However, complete disruption of the leaf matrix, for example by extensive cooking can also destroy carotenoids molecules (Rahman *et al.*, 19990).

In the present study there was a considerable range in percentage accessibility of β -carotene (8-29 %), from different leaves cooked without oil. This might be explained by different cell matrices of the vegetable varieties. Depending on vegetable source, cooking with sunflower oil or red palm oil increased the released amount of β -carotene by 3-20 times. It is well established that presence of dietary fat provides a hydrophobic domain within which carotenoids are solubilized and is known to stimulate bile flow, which is important for the formation of micelles from which carotenoids are absorbed into the mucosa (Parker, 1996; Furr and Clark, 1997). Enhanced bioaccessibility and absorption due to dietary fat has been shown in animal studies where consumption of cooked vegetables containing oil resulted in a significant increase in serum retinol concentrations (Jalal *et al.*, 1998; Takyi *et al.*, 1999; Huang *et al.*, 2000). The carotenes in red palm oil seemed to be highly available for absorption, as the leaves cooked with this oil had about twice as much in vitro accessible β -carotene as the ones cooked with sunflower oil. In the present study, depending on vegetable species, 39 to 94 % of the β -carotene content became available for absorption after cooking with oil.

Contribution of carotenes from vegetables to vitamin A requirement. There has been an extended discussion about the impact on vitamin A status with a diet consisting of dark-green leaves. De Pee *et al.* (1995) reported that the vitamin A status was not

improved when lactating women in Indonesia received stir-fried dark-green leafy vegetables as a daily supplement for 12 weeks. In contrast, increased serum retinol concentrations were found in three studies on children after consumption of green leafy vegetables (Jayarajan *et al.*, 1980; Takyi, 1999) or red sweetpotato (Jalal *et al.*, 1998) prepared with cooking oil.

The conventional conversion factor adopted by FAO/WHO (1988) for converting provitamin A carotenoids to retinol assumes that 1/3 of the total carotene content is absorbed into the mucosa and that 1/2 and 1/4 of absorbed β - and α - carotene are converted to retinol, respectively. In this study these conversion factors were used to estimate how much a portion of each vegetable relish might contribute to the recommended safe daily intake level of vitamin A, but instead of the absorption factor 1/3 the *in vitro* digestion data obtained in this study was used. The assumption made was that 100 % of the carotenes released after *in vitro* digestion is absorbed into the mucosa. The calculated amount of retinol was divided by the recommended safe daily intake level of vitamin A as adopted for planning purposes for individuals in developing countries, i.e. 550 μ g RE (WHO, 1995). According to the results from present study, one portion (100 g) of green leaves cooked without oil may only constitute from 12 to 47 % of an individual's daily need of vitamin A, whereas green leaves cooked with either sunflower oil or red palm oil may provide enough daily retinol.

Conclusion

Sweetpotato leaves and cassava leaves like other dark green leafy vegetables have a potential of providing adequate vitamin A if prepared with oil. However, it is recommended that vegetables should be treated in a proper way to avoid loss of carotene content before and during cooking.

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Promoting indigenous wild edible fruits to complement roots and tuber crops in alleviating vitamin A deficiencies in Uganda

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Abstract. Micronutrients lack in most of the foods eaten by majority of Ugandans and consequently, micronutrient malnutrition is so high in Uganda. Due to low incomes, many people cannot afford to buy exotic sources of these nutrients. Local sources of nutrients should be sought, as a food-based approach to complement supplementation and fortification efforts that currently leave a lot of ‘hard to reach people’ not served. Indigenous fruits could be such nutrient sources. Unfortunately the nutrient content for most of them is not known. Chemical analyses were carried out on *Physalis minima* and *Carissa edulis* fruits and indicated that they are rich sources of micronutrients especially minerals. These indigenous fruits compared well with the exotic ones (mangoes, paw paws and *Physalis peruviana*) in nutrient content.

Introduction

Like many developing countries, Uganda has nutritional problems. The food on which the majority of Ugandans feed lacks essential nutrients. Consequently, many people especially children, suffer from malnutrition. Uganda, ranks 30th among countries with the highest under- five year’s child mortality rates in the world (UNICEF, 1998). According to UDHS (2000/01), 28% of children in Uganda below 5 years of age suffer from vitamin A deficiency (VAD), 64% suffer from iron deficiency anaemia (IDA) and 60% suffer from

various iodine deficiency disorders (IDD). Over 50 percent (52%) of women of reproductive age suffer from vitamin A deficiency and 30% from iron deficiency anaemia. Reddish, yellow and orange fruits provide carotene and many contain folic acid, calcium, iron, vitamin C and anthocyanins (FAO, 1988). Fortunately, Uganda is endowed with many varieties of such indigenous food plants (WWF, 1993) that have an outstanding potential to alleviate nutritional deficiencies among vulnerable groups. Unfortunately, utilisation of indigenous food plants has steadily declined mainly due to lack of knowledge on their nutrient value resulting from limited research done (Kiremire *et al.*, 2002). These fruits are further threatened by population pressure in the country and man’s activities like clearance of forested areas to set up farmlands. A large proportion of Ugandans cannot afford to produce or buy exotic fruits due to input costs and price implications respectively. This could partly be responsible for the observed high malnutrition especially in micronutrients. Apart from providing nutrition to the diverse bird community, these indigenous nutritious fruits have not yet been given serious attention in Uganda. This paper presents the nutrient content of two wild edible fruits wild plums (*Carissa edulis*) and goose berries (*Physalis minima*) as a deliberate effort to promote consumption of locally available and easily accessible indigenous fruits in alleviating vitamin A deficiencies. The dietary

diversity that will be created could go along way in alleviating the nutritional problems that are facing Uganda and Africa in general. Comparison of nutrient content of these wild fruits with the cherished exotic ones like mangoes and paw paws revealed a fair comparison.

The aim of this study was to highlight the potential of fighting malnutrition in Africa using the locally available and easily accessible food plants by determining the nutrient content and promoting utilisation of indigenous fruits.

Materials and methods

The fruits that were studied were got from the wild in Rukungiri District, South Western Uganda.

Nutrient content analyses. Proximate analyses on crude protein, crude fat, dietary fibre and micro nutrient determination of β -carotene, vitamin C and minerals (calcium, iron phosphorus, magnesium and potassium) were carried out.

Moisture content. Moisture content (MC) determination of the samples was carried out following procedures in Kirk and Sawyer (1973). Aluminium dishes were washed, dried in the oven, removed and allowed to cool in a desiccator. The dishes were weighed empty (A) and after adding the samples (B). The sample-containing dishes were placed in the oven and the oven temperature adjusted to 65°C and left overnight. The samples were then removed, placed in a desiccator to cool and weighed again (C) and the MC of the sample was calculated.

Crude protein determination: The Kjeldahl method that is outlined in Pearson's laboratory techniques (1973) and AOAC (1990) was followed. Samples were macerated in a blender and about 1g of each sample weighed in previously washed and dried Kjeldahl flask. One tablet of Kjeldahl catalyst was added to the flask. 10mls of 98% H_2SO_4

were added to Kjeldahl flask and the flask was heated starting lightly (350°C) and finally heating strongly (500°C). Heating was continued until the sample in the flask turned colourless. Distillation was carried out using a semi auto Kjeldahl machine (2200 Kjeltec auto distillation). The sample was quantitatively transferred to the distillation tube. Kjeldahl flasks were washed twice with 25ml portions of distilled water adding the washings to the distillation flask. 30mls of 2% boric acid were measured into a 500ml conical flask and the conical flask was placed in position to collect the distillate making sure that the air condenser was immersed in boric acid. The distillation was continued until the colour of boric acid changed from purple to green. The distillate was titrated against standard hydrochloric acid solution (0.05N) and results were computed based on titres.

Crude fat determination. The Soxhlet method (AOAC 1990) was followed using Soxtec equipment for determination of fat content. The sample was weighed in a dry thimble (Swt), a pad of cotton wool was inserted into the thimble to prevent the sample from overflowing through frothing. A 200ml beaker was weighed (W_1) and 30mls of petroleum spirit (boiling point 40-60) were added. The sample-containing thimble and the beaker were placed on the soxtec machine (Soxtec system HT). Boiling was started with the thimble immersed in solvent for 15 minutes. The thimble was raised and extraction carried out for 45 minutes. Stop corks of the machine were closed and solvent distilled off the extracted oil in the beaker. The beaker was removed, put in the oven at 100°C for 30 minutes to drive off any water. The beaker was put in a dessicator and allowed to cool before weighing it (W_2) and the percentage fat content was calculated.

Dietary fibre determination. The dietary fibre was determined using Acid Detergent Fibre (ADF) solution following procedures outlined by Kirk and Sawyer (1973). The solution was prepared as follows: 28mls of 98% H_2SO_4 were

carefully added to and mixed with 600 ml of distilled water. 20g of Cetyl trimethyl ammonium bromide (CTAB) were added and stirred until it dissolved. The acid detergent was made up to 1 litre with distilled water mixed thoroughly. The sample was macerated and 1.0g of the sample were weighed in an 1 litre beaker. 100mls of the acid detergent solution were added to the beaker followed by 2.0ml of dekalin. The mixture was heated to boiling under reflux for 1 hour. Heating was controlled to minimise foaming by adjusting the control knob. The sample digest was filtered with a crucible previously dried in the oven at 100°C. The beaker was washed with boiling distilled water filtering the content through the same crucible 3 times. The final washing was done with acetone and the residue was collected into a clean crucible dried at 100°C for 8 hours in the oven. Dietary fibre of the sample was calculated. 2.1.5 Vitamin C determination: Vitamin C was determined following procedures in Kirk and Sawyer (1973). 5g of sample were weighed into a clean mortar. The sample was macerated in a mortar using a pestle with 5ml portions of 5% trichloro acetic acid (TCA) being added at a time. The extracts were quantitatively transferred into a clean 50ml volumetric flask and made up to volume with TCA. The flask was stoppered, shaken to ensure thorough mixing and the mixture was filtered using a filter paper (Watman no.1). 2,6-DCPIP Solution was standardised using ascorbic acid standard solution of concentration 1.08 mg/ml. 2mls of standard ascorbic acid were titrated with DCPIP until a pink colour that persisted for 3-5 seconds was seen. 5mls of extract were pipetted into a clean conical flask and carefully titrated against the standard DCPIP solution until a pink colour that persisted for 3-5 seconds was observed. The volume of DCPIP solution used was read from the burette and used to calculate the vitamin C content of the sample.

β-carotene determination. β-carotene was determined following procedures outlined by Ritter and Purcell (1981).

Extraction of β-carotene. Samples were separately weighed out and placed in a mortar; 5-7mls of hexane-acetone mixture in a ratio of 1:1 were added. A pestle was used to stir the sample-solvent mixture to facilitate extraction. The extract was transferred to a 50ml volumetric flask and extraction was repeated 5 times with 5-7ml portions of solvent mixture adding the extract of volumetric flask each time to the flask contents. When the sample was free of beta-carotene, the volume of the extract was made up to 50mls with the solvent mixture. The volumetric flask was kept away from light by wrapping it with aluminium foil to prevent photo degradation of beta-carotene.

Concentration of beta-carotene. The extract was placed in a clean, dry 100ml beaker and the beaker was heated gently on a hot plate in the fume cupboard with the fan on until all the solvent evaporated. The beaker was then removed and allowed to cool after which 2.0mls of pure solvent mixture were added to dissolve the residue; 1.0ml of the dissolved extract was pipetted and transferred to a packed column of magnesium oxide. A fresh solvent mixture was used to elute the extract from the column. The deep coloured band of beta-carotene was collected in a 50ml volumetric flask until the eluate was colourless, the extract was made up to volume, with the extracting mixture, shaken to dissolve and put in the dark ready for absorbance reading. 15mg capsules of beta-carotene were dissolved in 100mls of hexane to make stock solutions. Using a spectrophotometer (SP 20), the absorbencies of the stock solutions were read at 450nm. A standard curve of absorbance Vs concentration (microgram/ml) was plotted. Using a spectrophotometer (SP 20), absorbencies of the samples were read. By using their absorbencies, the beta-carotene concentrations of the samples were read off the previously prepared standard curve.

Mineral content determination. The mineral content of the samples was determined

following procedures by Kirk and Sawyer (1973) and AOAC (1990). Samples were digested with the digestion mixture prepared as outlined: 0.42g of selenium powder were weighed into a beaker. 14g of lithium sulphate were added followed by 350ml 30% hydrogen peroxide and mixed well. 420ml of conc. H_2SO_4 were added slowly and carefully while cooling in an ice bath. 0.2g of ground sample was added into a dry clean digestion tube and 5mls of digestion mixture were added to the tube. The mixture was digested at 360°C for 2 hours until the solution turned colourless. The contents were allowed to cool and 25mls of distilled water were added and shaken until no more sediment dissolved. The volume was made up to 50ml with water and shaken. They were allowed to settle and the clear solution was decanted off for phosphorus, calcium, sodium, Iron, magnesium and potassium analyses.

Phosphorus determination. 12g of ammonium molybdate were dissolved in 100mls of warm distilled water and then cooled. 0.291g of antimony potassium tartrate were separately dissolved in 100mls of distilled water. Both solutions were made to 2l with distilled water. The mixture was shaken thoroughly to ensure proper mixing. Ascorbic acid reducing reagent was prepared by dissolving 2.108g of ascorbic acid into 400mls of ammonium molybdate/antimony potassium tartrate. Working standard solutions of 0.1, 0.2, 0.4, 0.6 and 0.8-ppm concentration were prepared. 0.5 ml aliquots of the working standard solutions were transferred to a 25ml volumetric flask and diluted with distilled water followed by 5mls of the ascorbic acid reducing reagent. The mixture was made to the mark with distilled water and mixed thoroughly. The mixture was left to stand for 40 minutes prior to absorbance reading on a spectrophotometer (SP20). Similar procedures were followed to take absorbance reading of the samples. A calibration curve of absorbance against concentration was plotted using the working standard solutions. Phosphorus concentrations (ppm) in the samples were read from the calibration curve

using the previously obtained sample absorbencies. The phosphorus concentrations in the samples were then computed to mg / 100g of the edible plant portion. In the analysis of magnesium, sodium, calcium, potassium and iron, working standard solutions were prepared for each element from the stock solutions. Standard solutions and samples were prepared in a solution containing lanthanum chloride to overcome the problem of chemical and ionisation interferences. Working standards were then aspirated on the Atomic Absorption Spectrophotometer (Pearkin-Elmer 2380) so as to calibrate the machine to give its readings in milligrams per litre. Samples were aspirated on the calibrated Atomic Absorption Spectrophotometer and the concentration of each element in the sample solutions was read directly from the machine in milligrams per litre. The phosphorus concentrations in the samples were then computed to read in mg/ 100g of edible plant portion.

Statistical data analysis. Data were analysed using a one way Analysis of variance (ANOVA) using Genstat Version 5, Release 3.2 (Lawes Agricultural Trust Roth amsted experimental Station, USA).

Results and Discussion

Nutrient content of *Carissa edulis* and *Physalis minima*. Results of chemical analyses done on gooseberries (*Physalis minima*) and wild plums (*Carissa edulis*) indicate that they compare well with mangoes and paw-paws (Table 1, Figure 2). *Physalis minima* compares very well with its exotic counterpart, *Physalis peruviana*, in sodium, iron, phosphorus, calcium, beta-carotene, phosphorus and dietary fibre content. *Physalis minima* is however higher in protein content than *Physalis peruviana* and lower in potassium content (Figure 1). No significant difference in minerals like calcium, sodium, potassium, phosphorus, iron and other nutrients like dietary fibre and beta-carotene were observed between these two

fruits. *Carissa edulis* was equally high in minerals. People fear to get embarrassed by harvesting and consuming wild fruits. Malnutrition has taken advantage of this and left many of them either severely or chronically malnourished. Malnutrition leads to an unproductive population that cannot ensure its food security and this exacerbates poverty. Tackling malnutrition on the African continent

will go a long way in ensuring food security and improving the economic well being of the Africans. Domestication and conservation of the currently wild, nutritionally sound, environmentally adapted and locally available fruits along with the exotic ones will go along way in alleviating malnutrition and will ensure dietary diversity that is a close correlate to household food security.

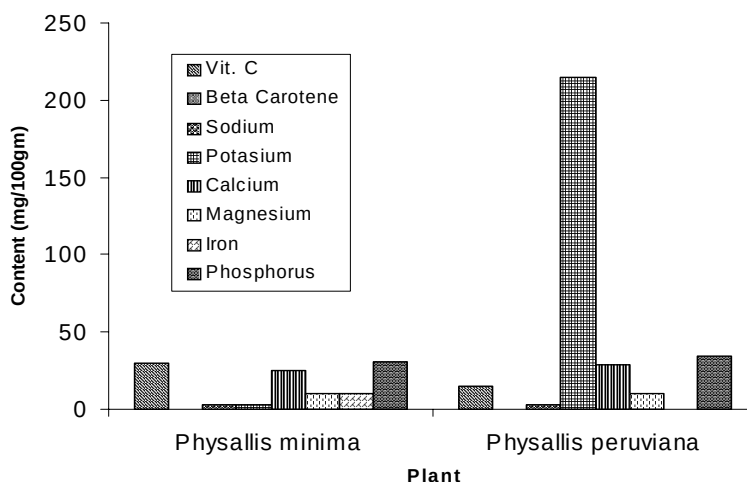


Figure 1: Nutrient content in *Physalis minima* and *Physalis peruviana*.

Table 1: Nutrient contents of *Physalis minima*, *Carissa edulis*, *Physalis peruviana*, mango and paw paw fruits (ripe and fresh) compared.

Nutrient	Content per 100g				
	Mango	<i>Physalis peruviana</i>	Paw paw	<i>Physalis minima</i>	<i>Carissa edulis</i>
Moisture content (%)	84.6	90.1	88.5	89.9	84.6
Crude protein (g)	0.5	1.1	0.5	2.04	0.3
Fat (g)	0.2	14	0.1	0.056	Trace
Vitamin C (mg)	37	114	60	29	3.24
Retinol equivalent (ig)	300-3000	18.3	810	28.9	256
Sodium (mg)	2	2	5	1.8	1.79
Potassium (mg)	180	210	200	2.43	198
Calcium (mg)	12	28	23	25	10
Magnesium (mg)	13	7	11	7.8	4
Iron (mg)	0.7	0.3	0.5	0.28	0.56
Phosphorus (mg)	16	34	13	30	24
Dietary fibre (g)	2.6	2.4-2.9	2.2	2.7	2.65

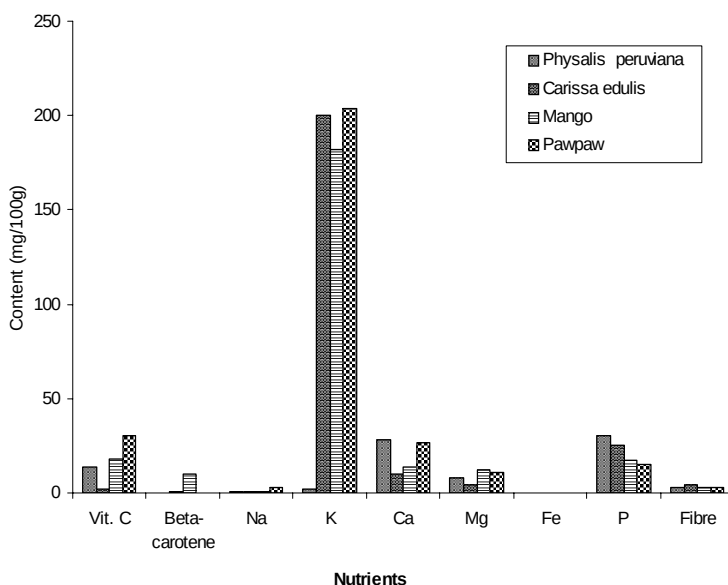


Figure 2: Nutrient content of *Carissa edulis*, *Physalis minima*, mango and pawpaw.

Conclusion and Recommendations

Carissa edulis and *Physalis minima* are as nutritionally important as the exotic fruits. There is too much stigmatization on indigenous fruits due to the notion that they are nutritionally inferior and are a poor man's food. Such stigmatization can be broken down with proper sensitization of the public. Research therefore should be done on more indigenous fruits and results of such studies be disseminated to the public. This will ensure dietary diversity and food security of marginalized and poor communities that make up the majority of the developing world.

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Effect of emulsifiers on sensory acceptability of cassava flakes

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Abstract. Reconstituted cassava flakes mash becomes sticky, so emulsifiers are normally added to improve their textural characteristics and sensory quality. Three types of emulsifiers were added to cassava flakes: glyceryl monostearate (monoglyceride), sodium caseinate and skim milk. Sensory scores from 12 judges showed that, the use of glyceryl monostearate (monoglyceride) significantly reduced the stickiness and resulted in a whiter mash. Cassava flakes mash with sodium caseinate and skim milk powder were sticky and dark in colour reducing their sensory acceptability. Pasting characteristics of cassava flour and flakes by

the Brabender amylograph indicated that, samples with glyceryl monostearate had low viscosity. This is due to the ability of glyceryl monostearate to reduce starch granules gelatinisation. Starch granules from flakes with sodium caseinate and skim milk powder, gelatinised and burst completely, which resulted into a sticky reconstituted mash. Reconstituted cassava flakes mash with glyceryl monostearate (monoglyceride) was mealy, thus acceptable like freshly cooked cassava mash.

Partnership: An approach to promote orange-fleshed sweetpotato, experiences from Uganda

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Abstract. Micronutrient malnutrition, is widespread in Uganda. In late 2000 a partnership using a multisectoral approach was initiated to address vitamin A deficiency (VAD) using orange-fleshed sweetpotato (OFSP) in a community in five zones of Luwero district in Central Uganda. The partners from different organizations and sectors field-tested OFSP in the district, created awareness of the potential value of OFSP in combating VAD, improving food security and household income. The initial partners were the National Agricultural Research Organization (NARO), the International Potato Centre (CIP), Child Healthy and Development Centre of Makerere University Medical School, Luwero District Agricultural Extension (LDAE), and the non-government Organization, Volunteer Efforts for Development Concerns (VEDCO). To accelerate promotion and dissemination of OFSP the partnership at different times included different players from the different sectors. To date more than 30 districts in the country have received planting material to initiate multiplication and dissemination of OFSP. Promotion of OFSP is increasingly attracting the private sector leading to new sweetpotato products, increased sale of OFSP vines and storage roots by farmers. The multisectoral approach involving different partners has had a positive impact as reflected in the increased demand for OFSP planting

material from research institutes and agricultural development research centers, individual farmers and farmer groups.

Introduction

Micronutrient malnutrition, primarily due to diets poor in bioavailable vitamins and minerals is widespread in Uganda, and in developing countries. Iron, vitamin A and zinc deficiencies are the most widespread nutrition deficiencies in the world today, affecting over 3.5 billion people globally (Ruel, 2001). The root cause of micronutrient malnutrition is poor quality diets, characterized by high intake of food staples, but low consumption of animal and fish products, fruits, lentils, and vegetables, which are rich sources of bioavailable minerals and vitamins. Consequently, most of the malnourished are those who cannot afford to buy high-quality, micronutrient-rich foods or who cannot produce and consume these foods.

More than 90 countries are categorized by the World Health Organization (WHO) as having a public health problem as a result of clinical (very severe) and/or sub-clinical (severe) vitamin A deficiency (WHO, 1995). Uganda is included in the clinical vitamin A deficiency category (WHO, 1995) due to approximately one third (28%) of Ugandan children, and 60% of women being vitamin A

deficient (UDH, 2001). Globally, an estimated 3-million preschool-age children have visible eye damage due to vitamin A deficiency (VAD). Annually, an estimated 250,000 to 500,000 preschool children go blind from this deficiency, and about two-thirds of these children die within a few months after going blind. VAD increases children's risk of common illnesses such as respiratory and diarrheal diseases, measles, and malaria, impairs growth, development, vision, and immune systems, and in severe cases results in blindness and death (Ruel, 2001). In women Vitamin A deficiency increases the risk of dying during pregnancy, as well as giving birth to low weight children and may increase the spread of HIV infection leading to AIDS. There are several approaches that are effective in combating vitamin A deficiency. These include, capsule supplementation, food fortification, diet diversification and public health measures. The rural and urban poor cannot afford expensive vitamin A-rich foods, such as fish oils, liver, milk, eggs and butter, which contain vitamin A in its true form (retinol), which can be used directly by the body. Plant foods and vegetables contain precursors, or pro-vitamin A (beta-carotene) and other carotenoids that the human body can convert to vitamin A.

Food-based strategies to combat vitamin A deficiency may involve modifying people's diets, by providing plants with large amounts of b-carotene or by breeding new varieties of plants with larger amounts and more bioavailable b-carotene. As a long term goal to combat VAD, consumption of a variety of local foods rich in vitamin A will provide adequate vitamin A. Consumption of these foods requires purchasing them or producing and consuming them on small holder farms of low income families. OFSP have potential to provide adequate vitamin A intake to the resource-poor, especially children. Prior studies have shown that OFSP are among the most promising plant sources of β -carotene (Low *et al.*, 1979; 2001; Hagenimana *et al.*, 1999; Mukherjee and Ilngantileke, 2002). This paper highlights the important role

partners have played in dissemination of OFSP in Uganda.

Early Attempts to introduce OFSP in the farming systems of Uganda. There were attempts to introduce OFSP in the farming systems of Uganda in the early 1980s but failed. Farmers and consumers rejected OFSP clones introduced from Taiwan, Mainland China, and the International Institute of Agriculture (IITA) because of low dry matter content (<30%) and squash-like flavor of clones (Mwanga *et al.*, 1991). In 1999 the National Agricultural Research Organization (NARO) officially released the "NASPOT 5", the first OFSP cultivar to be released by the national sweetpotato program (Mwanga *et al.*, 2003). However, dissemination of "NASPOT 5" was very slow. In an independent project, attempts by Child Healthy and Development Centre (CHDC) of Makerere University to improve child growth through improved quality of diet by promotion of rabbit rearing in Luwero District in mid 1990s failed. These plus perhaps other examples of previous undocumented interventions of supplementation, agricultural interventions, and education to improve dietary quality were all necessary but insufficient approaches. Coordination between sectors was missing. Multidisciplinary teams had to work together as partners to design and implement strategies to tackle the problem in a sustainable way.

Food-based approaches focus on increasing the amount of micronutrients consumed in the diet and on making a larger share of these nutrients bioavailable (readily absorbed by the human body). Food-based approaches are complex and require collaboration or partnership between a variety of sectors such as agriculture, nutrition, education, and economics. The realization of the need for a partnership and sector approach led to initiation of the Luwero Child Nutrition Project and eventually to the promotion of beta carotene-rich OFSP.

Background to the Luwero Child Nutrition Project. In 1997 The Child Health and

Development Centre (CHDC) of Makerere University (MU) together with Volunteer Efforts for Development Concerns (VEDCO), implemented a child nutrition project in 5 zones in Luwero District. The major objective of the project was to promote child growth through improved quality of diet. The activities included promotion of rabbit rearing for household diet, especially for children, monthly weighing of children, nutrition education, individual counseling and referral of mothers with malnourished and sick children, periodic distribution of vitamin A capsules and deworming medication. Rabbits had already been introduced to Luwero by VEDCO as an economic initiative. CHDC therefore came in to add value to the rabbits by promoting them for household consumption, for the benefit of children and to address micronutrient malnutrition. VEDCO and Luwero District Agricultural Extension (LDAE) provided extension services in rabbit management and rearing, and other agricultural related services. The Thrasher Foundation, a US based research initiative, funded the project during 1998 to 2000.

The Orange Fleshed Sweetpotato Project in Luwero District. In late 2000, the International Potato Centre (CIP) approached Micronutrient Operational Strategies and Technology (MOST) through the CHDC, to identify a community where the 'orange-fleshed sweetpotato project' could field-test OFSP to address vitamin A deficiency. The opportunity was seized by CHDC to continue providing services for nutrition improvement services already implemented in Luwero District. The National Agricultural Research Organization (NARO) through Namulonge Agricultural and Animal Production Research Institute (NAARI) and Kawanda Agricultural Research Institute (KARI) were included to plan for field-testing of sweetpotato in the existing project areas. Sweetpotato was considered a viable product for the project since 80% of Luwero households depend on sweetpotato as a staple food.

Implemented Project Activities

The partners (shown in parentheses below) implemented different components of the project in five zones of Luwero District.

Growth promotion (CHDC/MU, Healthy Department Luwero District, VEDCO). The partners executed monthly weighing of children, nutrition education and counseling, periodic deworming, and vitamin A capsule supplementation.

Crop and Field Management (NARO/NAARI, CHDC, CIP, VEDCO). The partners conducted demonstrations on garden-preparation, planting technology and crop management, and on-farm field-testing of OFSP clones. Rapid multiplication of planting materials was carried out to ensure availability of vines to farmers in each zone.

Post-harvest Technology (NARO/KARI, NAARI, CIP, CHDC, VEDCO, Luwero District Agricultural Extension (LDAE)). The partners: (1) carried out demonstrations on processing of sweetpotato into various products suitable for young children's meals. (2) Provided hands-on experience in preparation of children's meals. (3) Demonstrated technology for preservation and storage of sweetpotato for long time use. (4) Conducted palatability tests to measure acceptability of sweetpotato varieties and products.

Monitoring and evaluation (NAARI, CIP, CHDC, VEDCO, LDAE, farmers). NARO together with farmers specifically monitored crop management and emerging field problems. NARO also compiled data to assess yield performance, disease, pest resistance, and palatability of the different sweetpotato varieties. Other aspects of the project such as responses of the communities to project benefits were jointly monitored by all the partners.

Project Achievements

The following were the major achievements of the Luwero OFSP project accomplished through a strong partnership of various collaborators, including the community.

- Demand for nutrition and agricultural services were enhanced greatly.
- The project strengthened leadership of existing community groups to address not only economic empowerment, but also health and nutritional status of vulnerable groups like children
- Nutrition improvement for children was put on the communities' priority agenda. Communities demonstrated this through the implementation of community-initiated children's days to promote what they had benefited from the project.
- The OFSP project was appreciated as a means of improving household food security because the OFSP was high yielding and grew faster. It was nutritious and was liked by children. It is also a viable income-generating product of the project.

The Luwero Community. The community was led and organized by five leaders from each project zone. The leaders were responsible for mobilization, and training of community members. They were also responsible for monitoring progress of implemented activities.

Volunteer Efforts for Development Concerns (VEDCO). VEDCO is a community-based organization whose mission is to ensure sustainable economic empowerment of smallholder farmers and micro-entrepreneurs, organized in self-help groups. The organization acted as an entry point to the target communities, for implementation of nutrition-related activities.

Child Health and Development Centre (CHDC), Makerere University: provided the technical input on nutrition and health for growth promotion.

National Agricultural Research Organization, (NARO).

Two research institutions, NAARI, and KARI together with CIP, conducted extensive collaborative research on the OFSP, internationally and in Uganda. NARO was responsible for introducing, breeding and field-testing of the sweetpotato cultivars. KARI coordinated post-harvest technology.

MOST, a USAID Micronutrient Program was responsible for co-ordinating and providing logistical support to the project through the CHDC, Makerere. The MOST strategy aims at reducing micronutrient deficiencies related to Vitamin A, anaemia and iodine deficiency through an appropriate mix of interventions constituting a complex, yet affordable program.

Emerging Challenges

The following were the major challenges that emerged during the project:

- To create awareness and continue to emphasize to parents that children are special and require special care to keep them healthy and well
- Have the OFSP widely available on the open markets and in all households
- Need to encourage more caregivers to attend monthly growth promotion sessions for nutrition
- Conduct research on the OFSP retention of vitamin A through the different processing methods
- Inadequate supply of OFSP planting materials
- Expansion of project to cover the whole of Uganda

Expansion of Partnership. Funding of the OFSP by USAID in Luwero District was short, 2001 to 2002 due to the AlKeida bombing of the twin tower in New York on September 11, 2001 that led to sudden budget cuts which affected numerous US funded projects. Although USAID funding of the OFSP project stopped in 2002, partnership activities

continued with partners funding different components from different funding sources. The following activities or events led to expansion of the activities to other districts and increased the number of partners. The expansion of the partnership and activities led to rapid dissemination of planting material of OFSP in Uganda.

The orange-fleshed sweetpotato promotion initiative. Promoting the OFSP is one of the ways of focusing on available Ugandan foods with added value. The OFSP promotion effort was started in the pilot District in Luwero in 1999 as a joint multi-sectoral effort involving NARO, CIP, VEDCO, Makerere University Medical School, Ministry of Health, Local Government and farmer groups, to introduce OFSP in the farming and food systems of Uganda.

To date the promotional effort has widened and includes many partners whose roles vary. The key ones are:

- 1) the National Agricultural Research Organization (NARO)
- 2) the International Potato Centre (CIP)
- 3) the Potato and Sweetpotato Network (PRAPACE)
- 4) Child Healthy and Development Centre (CHDC), Makerere University
- 5) Non-Government Organizations
VEDCO (Volunteer Efforts for Development Concerns), BUCADEF (Buganda Cultural Development Fund) JAF (James Arwata Foundation), SOCADIDO (Soroti Catholic Diocese Development Organisation), AFRI-CARE and World Vision
- 6) Senior Family Charity Foundation in the USA
- 7) Farmer groups,
- 8) CBOs (Community based organizations)
- 9) REFSO (Rural Energy Food security organisation)

Most of the sweetpotato breeding work to produce new OFSP cultivars and a large proportion of on-farm testing and technology

transfer is supported by the McKnight Foundation.

Role of local government and political leaders.

The role of local government and political leaders has had a significant effect in mobilizing and sensitizing communities to the problems of vitamin A deficiency and the great need to plant and consume OFSP to combat the deficiency. Below are examples where political leaders have been actively involved in sensitizing communities and/or dissemination of OFSP.

The Minister for Agriculture officiated opening of vitamin A for Africa (VITAA)-Uganda Workshop at NAARI (4-6 February 2002). The inauguration was televised and covered in local newspapers and radio. He urged all concerned to encourage every homestead to grow OFSP to combat Vitamin A deficiency. The Honorable Minister For Agriculture does not only promote use of OFSP to combat Vitamin A deficiency but he also grows it on his farm at Kikonde, Bamunanika in Luwero. He is practical. Representatives from the districts of Gulu, Lira, Kabale, Kisoro, Masindi, Kamuli, Soroti, Kumi, Busia and Pallisa who attended the workshop followed the example of the minister; they took OFSP vine cuttings to their districts to start sensitizing the local communities.

Queen of Buganda Launch of OFSP. Her Royal Highness, the Queen of Buganda, known locally as the *Nabagereka* launched a campaign at Nyimbwa Sub-county Headquarters near Bombo in Luwero District on May 15, 2002 to promote OFSP in the nine districts of Buganda in Central Uganda to combat vitamin A deficiency. The launch built upon two years of research by child health experts at Makerere University, NARO, and CIP. The Queen appealed to all Ugandans to grow and feed OFSP to fight malnutrition and poverty. Local officials named one of the new varieties *Nabagereka* to motivate Ugandan mothers to grow orange-fleshed plant types.

The *Nabagereka*, the official wife of the Kabaka or King of Buganda, is held in high esteem by her subjects and plays a pivotal role in mobilizing development efforts in the Buganda Kingdom which covers 10 districts in Central Uganda: Kiboga, Masaka, Wakiso, Mpigi, Mukono, Mubende, Kayunga, Luwero, Rakai, and Kalangala. During the launch, there were exhibits by farmers, research institutes and NGOs. Different cultivars of OFSP (Ejumula, SPK004, NASPOT 5, Sowola-6, Sudan, and Kala) and sweetpotato products such as chapatti, doughnuts, cakes, crackers, pancakes, porridge and bread were sold. The Luwero farmers sold OFSP vine cuttings at 10,000/= Uganda shillings (USD 5.00) a bundle of 600 vine cuttings of 30 cm length each. They also displayed and sold vines and products of the OFSP. The event was widely publicized on radio, television and newspapers. The Queen's launch of OFSP subsequently led to increased acceptance and high demand for OFSP.

The Uganda Parliamentarians' Forum on Food Security, Population and Development (UPFFPD). Involvement of the UPFFPD started during a meeting when all the Future Harvest centers based in Uganda were invited by the UPFFPD to address matters related to food security and income generation in Uganda. The parliamentarians had special

sessions (4/3/2003, 4/4/2003, May 2003) with NARO, CIP and NARO staff. The forum is an interest group of 60 members of parliament formed to advocate for and where possible implement and promote programs to improve food security and general livelihoods in the country.

CIP and PRAPACE used this opportunity to brief the forum on its research and development activities on potato and sweetpotato in Uganda and in other countries. It is this briefing that generated interest among the executive committee of the forum and requested for a follow up discussion on possible collaborative plans. Thereafter, NARO, CIP-VITAA and PRAPACE agreed to initiate follow up activities ranging from dissemination of planting materials of improved varieties of OFSP in pilot constituents to big proposal development to cover more than 20 districts in Uganda. It was at this point that CIP-VITAA together with PRAPACE provided support to the forum by providing starter-planting material of the popular varieties for a few pilot constituencies as indicated in the Table 1. It is also important to note that some parliamentarians ordered and got more planting material for their areas.

Five pilot constituencies were targeted by the forum to benefit from the planting material. These included mainly the cattle corridor in Katakwi and Kotido, which experience severe

Table 1: Distribution of OFSP planting material in pilot constituencies of Uganda through the Parliamentarians Forum on Food Security and Population Development, May, 2003.

Constituency	Number of bundles distributed*	Estimated number of cuttings	Estimated area harvested (ha)	Estimated of Households benefited**
Kotido	200	600000	20	6000
Katakwi	246	590400	19.7	5904
Jinja	110	264	8.8	2640
Rakai	80	168	5.6	1680
Kalangala	80	168	5.6	1680
Totals	636	1.430.400	59.7	17904

* A bundle has 800 vines each capable of giving 3 vine cuttings.

** Major assumption: Each targeted household receives at least 100 vine cuttings.

famine after prolonged drought and were largely supplied with orange-fleshed varieties SPK 004 (Kakamega) and Ejumula. Jinja district in the East was also targeted and received orange varieties. Rakai and Kalangala districts in the Central which experience frequent food insecurity yet grow and consume a lot of sweetpotato, were given the high yielding but yellow varieties, Tanzania and Naspot 1.

Source of OFSP and varieties supplied. All the vines were obtained from progressive farmers from Luwero and Mpigi districts who have concentrated in the multiplication of clean healthy planting materials of popular varieties as an income generating activity. The consignment supplied consisted of OFSP (81%) and others (19%). A bag consisting of 2400 vine cuttings is sold at Ugshs. 6000 = US \$ 3. These farmers originally participated in the first pilot NARO/ CHDC/ VITAA – USAID MOST project on the promotion of OFSP for the increased intake of Vitamin A in resource poor households of Luwero district. Although the project was concluded in May 2002, farmers have continued with the scaling-up of activities mainly multiplication and dissemination of clean healthy planting materials, development of OFSP based processed products, and storage root production targeting the markets. Interview reports, their experiences, farmers' experiences, and OFFSP success stories, and lessons learnt frequently appear on the VITAA web site.

Handing over ceremony

An official hand over ceremony was held on 15th May, 2003 at the premises of Uganda Parliamentary Chambers during which Dr. Fina Opiyo, the VITAA co-ordinator and Director of Namulonge Agricultural and Animal research Institute of NARO handed over two lorries full of sweetpotato vines to the Hon. Grace Akello the Chairperson of the Forum executive committee and by then was one of the state Minister for Ministry of Gender,

Labour and Social Development. About thirty parliamentarians from the forum witnessed this event. Also in attendance were partners from BUCADEF, CIP- Nairobi, PRAPACE, NARO and individual farmers from Central Uganda. The journalists from both the print and electronic media covered the function. It formed an item on the evening news broadcasted by the Uganda Television covering the all country and the Central Broadcasting Station (CBS), a private local radio station covering almost eighteen districts of Central Uganda.

The forum members exhibited a lot of enthusiasm and are still keen to promote the activities food security in their constituencies. Sweetpotato provides a great potential for the purpose due to its wide adaptability and acceptability to all Ugandan communities. However the forum is constrained by limited financial resources that are much needed to undertake the activities. CIP-VITAA, PRAPACE, and NARO remain committed to work with the forum to mobilize resources to cover larger areas in Uganda, particularly with orange-fleshed types. Technology transfer through this channel could have much impact at household level since they reach the grassroots. They can also link up quickly with the active community based set ups and the local governments in their constituencies to reach more people. High interest by the MPs has demonstrated the importance attached to food security crops such as sweetpotato to address food shortages in their areas.

Dissemination and commercialization of orange-fleshed sweetpotato through Farmer Field Schools and VITAA partnerships in Eastern Uganda. Farmer field schools (FFS) integrated crop management of sweetpotato started in August 2001 and the orange-fleshed varieties were introduced during launching of OFSP to combat VAD on September 27, 2002 in Gweri sub-county, Soroti district. All the vines were sourced from Luwero district, Nyimbwa sub-county. Since the launching 872 bundles of 600 vines each worth Ug.Sh. 5,232,000 have been bought from original

farmers where CHDC worked in partnership with CIP, NARO, VEDCO, and PRAPACE. Farmers from Luwero went to Soroti and trained their fellow farmers in agronomic practices, product development, and rural income generation through the sale of OFSP (Table 2). In 2002 two FFS (Apa Amora and Okunguro) in Kyere, Soroti District sold about 700 kg of dry chips to Maganjo factory in Kampala for further processing into nutri-porridge flour.

Projections. Slicing and immediate sale of dry chips of OFSP stimulated interest by individuals and other groups in Soroti District for further production of orange-fleshed varieties, and by 2003, nine farmer field groups, 20 SOCADIDO community-based groups in Kumi and Soroti districts, several individual spill over within and beyond the project areas such as Bugondo had grown the orange fleshed varieties namely Ejumula and Kakamega (SPK004). A conservative figure of above 70 acres was grown in the second season of 2003 alone and was estimated to produce not less than 700 tons of fresh roots.

Sustainability. Soroti local government and National Agricultural Advisory Services (NAADS) program have internalized the orange-fleshed varieties as a commercial crop in selected sub-counties. The district leadership and CIP is spearheading the search for and linkage to alternative markets such as

encouraging consumption of orange-fleshed in boarding schools and other factories including those processing animal feeds. Key district leaders urged their people to grow more orange-fleshed varieties for domestic and outside district market, and encouraged the producers to include OFSP on their daily menu to alleviate the nutritional deficiency of Vitamin A.

Lessons learnt from the fields.

Commercialization through processing seemed not profitable meanwhile the use of feeding to boarding schools was more promising. Awareness of the crop about its nutritional and marketability benefits promotes popularity. Through FFS an inferior crop can be easily be popularized. Farmers can accept to pay for the cost of inputs where they expect tangible returns. Farmers have a potential to supply quality-planting material after internalizing the concepts and practices learnt through self-learning approach. Farmers' collective participation is a tool of capital mobilization and a driving ingredient for self- accountability as skillful performance and financial improvement by the group member(s) portrays community excellence. Farmers are thirsty for a positive change in production and income. Evidence of economic success through changed technological approaches to production by farmer field graduates is not only exemplary but also creates anxiety of others to explore similar

Table 2: Distribution of orange-fleshed sweetpotato planting material in Soroti District, Uganda.

Season	Beneficiary	Source	Bags	Cost/bag	Total cost Ug. Shillings	Paid by
2002	SOCADIDO	JAF	256	6000	1,536,000	SOCADIDO
	NAADS	JAF	600	5,000	3,000,000	NAADS
	Launching	CIP	27	8,000	216,000	CIP
	FFS groups	CIP	20	6,000	120,000	CIP
	FFS groups	Gweri	16	5,000	80,000	FFS
2003	FFS groups	CIP	196	5,000	980,000	CIP
	FFS groups	Gweri	45	5,000	225,000	FFS
Total			1160		6,157,000	

avenues to improve farming techniques and enhance adoption as an avenue of improving on food security and household incomes. Researchers, NGOs, policy makers and farmers must collaborate in developing, designing and implementing strategies for transforming agricultural production and augmenting successful attainment. Experience sharing and availing opportunity to FFS member(s) to become technical instructor(s) (facilitators) of otherS promotes ambition, encourages active participation, enhance self-confidence and leadership building. Farmers are willing to drop a crop variety for a more promising one. Integrated crop management approach through experience sharing, self-teaching and a hands-on technique is a tangible technology uptake pathway for recommended practices.

OFSP in Disaster Mitigation. James Arwata Foundation (JAF) with support from NARO, CIP, Senior Family Charity Foundation in the USA and PRAPACE has distributed OFSP planting material in the war ravaged districts and donated OFSP roots to resettlements camps in Northern Uganda where Joseph Kony operates.

The private sector engagement in OFSP. This has gaining momentum as highlighted below:

- 1) The number of farmers selling OFSP vines, roots, and processed products is increasing
- 2) Maganjo Grain millers markets a composite flour that has OFSP flour as an ingredient.
- 3) Ugachick conducted trials to use OFSP flour in their chicken feed.
- 4) Training of CBOs and farmer groups in production of sweetpotato products such as bread, doughnuts, chapatti has stimulated growth of small-scale enterprises in villages in peri-urban centers.
- 5) HORTEXA (Association of Horticultural Exporters) exports sweetpotatoes, including OFSP to Europe.

Conclusion

There has been rapid dissemination of OFSP in Uganda. The initial pilot OFSP project covered five zones in Luwero District in Central Uganda in late 2000. The participating farmers had no OFSP planting material to start with. A multi-sectoral approach involving partners from different organizations, NGOs, the private sector (such as processors), community based organizations, individual farmers and farmer groups worked together. The partners provided OFSP cultivars to conduct participatory evaluation of OFSP, sensitization of the communities regarding the widespread vitamin A deficiency in the country and need to grow, consume and commercialize OFSP to alleviate the deficiency and poverty. The number of partners increased and dissemination of OPSP from the single limited localized research pilot area of Luwero District in central Uganda accelerated, reaching at least 30 districts by 2003. Some of them districts were already selling OFSP vines, roots and processed products by the end of 2003. The different partners attribute this success of rapid dissemination of OFSP to active sustained involvement by the partners.

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Dissemination and commercialization of orange-fleshed sweetpotato varieties through FFS and VITAA partnership: Experiences from eastern Uganda

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Abstract. Integrated Sweetpotato Management through farmer field schools was incorporated into the already established IPPM FFS (Integrated Pest and Production Management Farmer Field Schools) programme in East Africa. It was aimed at promoting sustainable sweetpotato production and post harvest management. After four months field implementation of this technology-based and farmer education project, partnership was forged with the VITAA (Vitamin A Africa) initiative to disseminate and promote commercial production of orange-fleshed sweetpotato (OFSP) varieties. Since then a cumulative total of 1622 bags of vines each containing 1800-2400 cuttings ready for planting worth Uganda Shs 9,732,000 (US\$ 4866) have been distributed to farmers through farmer-oriented organizations within Soroti district. More than 600 bags of OFSP vines have been distributed to farmers through FFS and VITAA promoting partner organizations. Whereas the other partners reported complete crop failure due to the adverse weather conditions during the first crop cycle, 2 FFS managed to produce orange-fleshed roots for processing and delivered about 1 metric ton of chips to Maganjo processing factory in Kampala. Of an estimated total of 72 acres of OFSP planted during the second cycle, 20% of the planting material was supplied by the FFS vine bank

plots. Two sub-counties have prioritised sweetpotato as a commercial crop through the NAADS programme. CIP provided two chipper machines to FFS and other sweetpotato producer groups in a bid to transform sweetpotato into an industrial crop and is spearheading the search for linkages to find alternative markets for chips. Although the pilot venture into commercialization through processing did not appear to be profitable, the idea of selling OFSP to boarding schools and other institutions seems to be a more promising alternative market.

Introduction

Sweetpotato is grown as a food crop in many Sub-Saharan Africa countries and covers an estimated 2.1 million hectares with annual estimated production of 9.9 million tones of roots. It is the third most important food crop in east Africa and ranked seventh among the food crops produced in the world and has an annual production of 138 million metric tons (Edison, 2000). Uganda is the world's second largest producer of sweetpotato and first in Africa. Sweetpotato plays a primary role in food security in Uganda especially in the eastern region where two crops per year are grown for both home consumption and to supplement household income by sale to local

markets and urban centres. Although crop utilization in urban centers was previously limited and often kept secret as it was considered to reflect the low income status of the consumer, it is becoming increasingly important in urban food systems and there has been tremendous positive change in attitude towards the crop.

In spite, of the increasing popularity of sweetpotato in both rural and urban food systems, most local varieties grown throughout the region have white or cream-coloured flesh, and supply little or no pro vitamin A in the body (Draft Sweetpotato Technical manual, 2003). Vitamin A deficiency is one of the major health problems which most developing countries currently face. This micronutrient is critically deficient in the diets of the majority of people in the east African region especially in rural areas, particularly young children. Severe deficiency leads to night blindness, while less severe forms reduce a person's general health and capacity to fight off malaria, measles, diarrhea, AIDS associated illnesses, pneumonia and other diseases. Vitamin A deficiency has been identified as the leading cause of early childhood death and a major risk factor for pregnant and lactating mothers in East Africa (FAO/WHO, 1992).

Whereas Food and Agriculture Organization's (FAO) food balance sheet indicates an improving trend of Vitamin A in the diets for most developing countries in the last 20 years, in East Africa the overall vitamin A supply is actually decreasing (United Nations, 1992). According to International Food Policy Research Institute (IFPRI) projections 2000, the number of the malnourished children will continue to increase from 33 million in 1997 to somewhere between 39 and 49 million in 2020.

According to FAO/WHO report 1992, vitamin A intake is often inadequate because of the seasonality of food sources, the early abandonment of exclusive breast feeding, high morbidity levels, and practice of not giving vitamin A-rich food to young children. Dependence on capsules donations from

UNICEF and use of fortified foods is quite costly and not implemented widely. The best sources of beta-carotene are liver and fish-liver oils, which are very expensive for the rural poor. The best plant sources of beta-carotene, which the body turns into vitamin A as needed, are carrots, green vegetables and orange-fleshed sweetpotato (OFSP). Whereas most rural people especially in eastern Uganda associate carrots with rich families and greens are regarded as inferior vegetables to be used during periods of scarcity, sweetpotato is traditionally regarded a famine crop that can substitute for cassava and fits in many food mixtures (blends) and forms.

To date countries tackling the Vitamin A deficiency problem are focusing actions largely on a combined approach of supplementation as a curative measure, promoting the increased production and consumption of Vitamin A-rich foods, and use of fortified products. Beta-carotene (precursor of vitamin A) reported as units of vitamin A activity in many studies is the most prevalent source of vitamin A in our foods (Colgan, 1995), and thus, the introduction of Vitamin A-rich sweetpotato in farmer-oriented programmes can play an important role in improving their nutrition and is amenable to agriculturally-based interventions (FAO and WHO, 1992). The OFSP varieties, which have previously been relatively uncommon in Africa, are providing their worth as a low-cost, easily available, natural, dietary source of pro-vitamin A. The total carotenoid content of sweetpotato has been found to range from 0 to > 20 mg/100g of fresh weight depending on the variety (Akoroda and Teri, 1998). Sweetpotato has a comparative advantage over other common staple foods especially cereals and legumes which provide zero to minor traces of beta carotene equivalents. Children below 5 years, 7-10 and adults need to eat about 30, 40 and 80g of OFSP respectively, to meet the daily requirements of pro-vitamin A therefore even if OFSP is not a preferred diet for an individual consumer, one needs only a small portion in addition to

the preferred choice and farmers with small plots can adopt it as a back garden crop to supply roots and leaves for daily household dietary supplementations (Third Draft Technical Manual, 2003).

International Potato Center (CIP) is providing support towards modern technological dissemination to improve on production, post-harvest handling and processing to add value (Tara, 2003). This would improve on the current fragile food security, low per capita income, and very low availability of Vitamin A in the diets, which according to the United Nations report 1992, Vitamin A supply in the East African region is actually decreasing due to seasonality of food sources, early abandonment of exclusive breast feeding and high morbidity levels. In recent years, technology dissemination through Farmer Field Schools (FFS) has been introduced to East Africa and is seen as a promising approach for sustainable technology adoption. Participatory systems approach is well suited to increasing rural incomes because they are tailored to the requirements of the villagers and build on the strengths and knowledge of the smallholder community (Chandra, 2000). Therefore, piloting promotion of OFSP activities through the recently started sweetpotato integrated pest and production management farmer field schools (SP IPPM FFS) groups set up as part of the UK Department for International Developments (DFID) Crop Protection Programme funded project 'Promotion of sustainable sweetpotato production and post-harvest management through farmer field schools in East Africa' would strengthen dissemination and technology uptake among farmers and other end users.

World Health Organisation (WHO) estimates that in many of the under developed and developed countries, several nutritional disorders are prevalent, and could easily be alleviated by consuming root and tuber crops like sweetpotato (Edison, 2000). According to VITAA Newsletter (2001), the Vitamin A for Africa (VITAA) partnership is promoting consumption, production and marketing of

OFSP varieties which have been lacking in the traditional farming systems. The partnership is extending the impact of OFSP varieties through community awareness of nutritional benefits. International Potato Center in collaboration with Soroti district agricultural extension agencies/National Agricultural Advisory Services (NAADS), research institutions, community-based organization such as Soroti Catholic Diocese Development Organisation (SOCADIDO), World Vision launched as an immediate action plan for establishment of OFSP varieties by facilitating distribution of planting material and awareness raising about vitamin A deficiency to potential sweetpotato farming communities. Since the launching of OFSP in Gweri sub-county in September 2002, CIP has continued to support sensitization seminars, workshops, radio talk shows and press articles involving a cross section of stakeholders. International Potato Center (CIP) facilitates the provision and delivery of planting material for commercialisation and evaluation, and is spearheading the promotion of OFSP as an industrial crop by encouraging processing and searching for viable market options.

Farmer Field Schools (FFS) are an effective and popular method of farmer education in which learning is through discovery and adoption. Farmer Field Schools have been found to be a successful technology dissemination approach in a number of countries including Indonesia, Sudan, Benin, Ethiopia and East Africa Federation (M'Boob, 2002) they facilitate increased farmer understanding of crop ecology and farmer experimentation combining and comparing indigenous and researcher developed technologies that allow farmers to evaluate and develop appropriate pre and post harvest crop management strategies for their specific farm conditions and needs. Farmer Field Schools have become popular entry point for most agriculturally -oriented programmes in Uganda including NAADS and Acquired Immunity Disease Syndrome (AIDS) Awareness activities. Technical staff in the traditional extension service or graduates of

previous FFS are contracted to facilitate the FFS throughout the cultivation season.

Participants are led through the growth and development stages of both the above and underground plant parts by using a hands on approach, or inciting leading to discovery and action. The language of guidance or instruction is preferably indigenous. Group dynamic exercises enhance togetherness and their sub-group session rotation as hosts, computation and result presentation leads to expression of their value of togetherness, mission understanding and leadership challenges. This has been manifested in a number of FFS graduates from previous Integrated Pest and Production Management (IPPM) FFS being elected to responsible positions within the community leadership councils, and the evolving of farmer facilitators' association with the aim of competing for provision of selected community services.

Inclusion of OFSP variety growth and performance assessment in FFS learning and commercial plots enhanced their dissemination and highlighted their nutritional importance. Participants sensitized on the use of OFSP, multiply varieties that have already passed consumer acceptance tests, evaluate agronomic performance of candidate accessions, produce OFSP roots for commercialisation, process OFSP for commercialization and grow them side by side in their own fields. Achievement days during which the community and influential people are invited are held to display the activities done during the season. Therefore the objectives of the partnership were to: 1) promote sweetpotato integrated field crop and post harvest management; 2) make orange-fleshed sweetpotato available on large-scale, demonstrating the potential of crop-based approaches in alleviating micro-nutrient deficiencies; 3) promote commercialisation through processing and utilization.

Strategies used for promoting OFSP varieties

Linking farmers to market. A meeting on linking sweetpotato farmers to markets was held on 5th Sept 2002 at SOCADIDO, Soroti chaired by Father Martin Aeho and attended by the marketing manager of Maganjo Grain Millers; sweetpotato farmers from potential sweetpotato growing areas in Soroti district, community development organizations (SOCADIDO and World Vision), researchers involved in sweetpotato improvement and post-harvest programmes, agricultural field extension workers, the CIP regional breeder, the SP IPPM FFS project assistant, and nutritionists. The goal of the meeting was to promote the socio-economic development of OFSP farmers and processors through integration of production, processing and marketing thereby linking a wide range of public and private sector institutions. During the meeting community-based organisations and farmers emphasised the lack of market as the most important limiting factor for large scale production because farmers tend to avoid excess root harvest for fear that they would not be able to dispose of them while in contrast processors represented by Maganjo Grain Millers singled out lack of chips from sweetpotato producers as a factor delaying effective inclusion of sweetpotato in their composite flour mixtures. Therefore strategies developed to promote both production and processing included: a) acquisition of vine stocks from central region, establishment of rapid multiplication plots and swamp nurseries to buffer up supply especially for immediate planting after prolonged dry seasons were components sighted for sustaining the seed systems in Soroti and Kumi; b) establishment of a sustainable rural-based sweetpotato processing enterprise to supply quality dried chips to identified market opportunities. CIP/PRAPACE pledged to provide two processing machines for the two groups that would be

identified as potential processors; c) identification of contract farmers to multiply seed vine of Ejumula, Kakamega and Naspot 5 orange-fleshed varieties for distribution to other farmers; d) a field day was planned to be held at Gweri sub-county as a central and potential sweetpotato growing area to sensitize the community on combating vitamin A deficiency and promote on-farm production of sweetpotato for home consumption and market.

The viability of commercializing production of OFSP varieties was estimated by assessing the expected production costs and compared with the processors' price offers. It was observed that during slack

seasons leading to limited root supply, processing was not profitable because the open markets would offer better prices for roots. However, participants noted the viability of piloting orange-fleshed processing as a first step towards promoting industrialisation of sweetpotato and stimulating increased production. Costs and profits at different levels of sweetpotato production and processing were estimated and indicated that commercial processing was not economical (Table 1).

Field day to launch OFSP varieties. Promotion activities for OFSP varieties launched at Gweri sub-county in Soroti, eastern Uganda in 200.

Table 1: Costs for processing 100 kg of dried sweet potato chips using powered chipper and raised tray dryers.

Item/activity	Details	Quantity	Unit price (US\$.)	Sub total (US\$.)
Fresh tubers	Farm gate price	3 bags (320kg)	4.00	9.00
	Peeling 3 bags	6 pers @ 4.5 hrs	0.13/pers/hr	3.38
	Washing	3 pers. @ 6 hrs	0.13/pers./hr	2.25
	Water	6 jerry cans (120 lts)	0.03/jerry	0.15
Slicing	Labour	2 pers.	0.13/hr/pers.	0.13
	Fuel	0.5 litres	0.70	0.35
	Oil	0.5 litres	0.50	0.25
Drying	Labour	2 pers./1.5 days	0.40/pers./day	1.20
Packing	Gunny bags	1	0.25	0.25
	Inner polythene	1	0.25	0.25
Transport	To Maganjo	100 kgs	0.01/kg	1.00
Total processing cost	Slicing, drying and delivery of to factory	3 bags of fresh roots (320 kgs)	6.07/bag	18.21
Production cost of dried chips	3.2 kgs fresh roots = 1 kg dry chips	100 kg	0.18	18.00
Factory price/kg chips	1 kg of dry chips delivered at factory	1 kg	0.18	0.18
Gross income	Sale of chips	100	0.18	18.00
Net profit	3 bags of fresh tubers or 100 kgs chips			0

The CIP regional breeder highlighted the efforts being taken by different partners and the importance of OFSP program for combating Vitamin A deficiency. During the function the VITAA Coordinator reported that the occasion was part of a series of planned promotional activities to be held in the country and other parts of Africa through the VITAA initiative. Success stories associated with OFSP cultivation and use in the central region of Uganda were shared with other participants. Demonstrations were carried out on sweetpotato production and processing and exhibition of sweetpotato products such porridge, and processed flour from Maganjo processing factory were displayed. Some planting materials of OFSP were also distributed.

Public and farmer - awareness seminars, talks, workshops. The district policy making body urged councilors to advocate for consumption of OFSP varieties. They also pledged to encourage educational boarding institutions to include OFSP in their weekly menus. Radio talk shows involving policy stakeholders were organized to promote production, consumption and marketing of OFSP varieties. During technical review workshops OFSP was highlighted as a cost-effective nutritional strategy for the majority of rural people. One commonly highlighted issue during the meetings was the comparison

of vitamin A levels in common staple foods and the vitamin A requirements (Table 4) which served as evidence to help justify the adoption of OFSP into the production systems and dietary habits.

Provision of the most limiting inputs. International Potato Center (CIP) in liaison with National Agricultural Organisation (NARO) and district farmer-oriented organizations namely NAADS and SOCADIDO facilitated the supply of OFSP planting material and two chipper machines on credit for pilot processing.

Promotion of production and post-harvesting technologies. Two pilots SP IPPM FFS with a total of 60 participants successfully completed the first field season in July 2003. A field day was held and OFSP products (doughnuts, pancakes, chapattis, cakes, crisps and chips) exhibited. These products sold off very fast and stimulated the demand for vines of these varieties and the scaling up of the project to a wider section of the community coverage. Therefore, 4 sweetpotato farmer field graduates who excelled during the first pilot cycle were selected for a week-long induction skills empowerment training at Namuloge Research Station so that they could boost the 2 extension-led facilitators and the number of could then be tripled during the second pilot cycle.

Table 2: Vitamin A levels (average per 100g edible portion) in common foods in East Africa.

Source	Form [Beta carotene equivalent (g)]						
	Fresh	Boil	Skin boil	Dried	Porridge	Bread	Leaves
Sweet potato	0-20,000		0-20,000	7,820			2,700
Cassava		0-20					8,280
Fresh maize		240					
Maize flour					0	0	
Rice		0					
Beans		Trace					
Carrots	12,000						
Tomato	600						
Cabbage		Trace					Trace

Table 3: Root flesh colour of sweet potato related to dietary supply of vitamin A

Age/sex	Vitamin A requirement (µg RE)	Amount (g) of fresh sweet potato roots required to supply the daily requirements of pro-vitamin A			
		Araka (white)	Osukut (yellow)	Kakamega (orange)	Ejumula (deep orange)
1 day-3 years	400	3636	265	78	35
4 to 6 years	500	4545	331	97	43
7 to 10 years	700	6364	463	136	61
Females over 10 years	500- 850	7273	530	156	69
Males over 10 years	500- 600	9091	662	194	87

Source: (Technical Manual, 2003).

Production profile of OFSP. Inspite of the poor weather conditions (drought) during the first pilot season the SP IPPM FFS participants managed to produce and supply OFSP roots for processing and conserved vines for subsequent season otherwise the non-FFS growers lost all their crop. Total OFSP acreage increased from 10 acres during first season to over 70 acres in the second cycle. About 10 tons of OFSP chips were produced by FFS in the first and second cycles respectively.

Promotion of processing and marketing. To kick-start the processing and marketing of chips, the NARO post-harvest programme extended a revolving fund to processors to pay for the roots and meet the costs involved in processing and transportation of dried chips to Maganjo flour milling factory. Continued efforts have been directed towards attracting alternative markets for dried chips such as Kirinyaga millers in Nairobi, Kenya and Ugachick poultry feed producers in Uganda. Maganjo flour products are available in most Supper Markets in Uganda. Preparation and utilization of various recipes is being encouraged through FFS.

Field achievement day. A joint field day organized by SP IPPM FFS project and Abuket Oyuunai Sweetpotato Processors to appraise the activities of farmer field school activities was held at Okunguro Farmer Field Schools (FFS) and attended by a cross section

of stakeholders. The event was officiated by the Local Council V (LCV) Chairman, the highest policy making organisation in the district. Field guided tours and demonstrations were conducted to explain the improved field production technologies, commercial sweetpotato chipping and preparation of various OFSP recipes were demonstrated and exhibited for sale. Local songs and a poem were sang and recited to express the usefulness of the SP IPPM FFS project.

Achievements - The partnership made the following achievements:

- Rapid dissemination increased production and consumption of OFSP varieties,
- Farmers appreciation of the commercial potential of sweetpotato and the successful linkage of primary processors to flour millers,
- Intra-institutional participation in promotion of OFSP varieties,
- Inclusion of sweetpotato on the priority list of Gweri and Kyere subcounties, and subsequent approval of funding by NAADS.

Lessons learnt by promoters and farmers

- Commercialisation through processing did not seem to be profitable while the sale of OFSP roots to boarding schools appeared

more promising. Further promotional strategies are being geared towards increased food processing and local fresh root consumption. It is important for food processors to focus at flour mixtures for both the medium class and traditional rural

markets whose stocks often run out during prolonged post-harvest seasons.

- Whereas farmers recognize that their production approaches result in low yields, they avoid opportunities that

Table 4: Institution responsibilities and significance of linkage to promotion process.

Institution(s)	Responsibilities	Importance of promotion process
NARO	Provision of basic seed and training in production techniques and post harvest handling	Availability of improved clean seed, product utilization /acceptability & technology empowerment
SOCADIDO/ World Vision	Seed distribution to communities and farmer group formation	Household food security, wide dissemination and adoption in every household in the communities, wide seed distribution
CIP	Provision of advanced clones and technical support	Variety dissemination, adoption and utilization/ acceptability & sustainability
SP IPPM FFS project (Global IPM Facility, CIP, NRI, NARO, KARI)	Project development for SP IPPM FFS, sourcing funds for FFS activities, project implementation, reporting, M&E, dissemination, mirror activities in W. Kenya & W. Tanzania	Implementation (Set up, fund, support and monitor all SP IPPM FFS activities and plan scaling up)
PRAPACE	Technical support	Market orientation and technology adoption
NAADS/DAO	Enhanced variety and technology dissemination and adoption	Modernisation of agriculture (Food and poverty alleviation)
Farmer groups	Field and post harvest evaluation, proper management and commercial production	Enhanced production, processing and marketing skills
COARD	Training farmers in seed multiplication, conservation and quality chip production	Enhanced production, processing and marketing techniques at farmer level. Training farmers in clean seed production and conservation, and quality chip production
Flour millers	Flour processing	Value addition and creating vertical sweet potato marketing
Policy makers	Sensitisation and project activities backing	Increased adoption, acceptability and approval of scaling up
Educational institutions	Provision of market and in-depth sensitization	Sustainable wide utilization multiple dissemination and adoption

result in excess harvests that may not be disposed off. The marketing opportunities being created for OFSP have enhanced technology up-take because farmers want to take advantage of presumed profitable opportunities.

- Orange-fleshed sweetpotato chips have poor mashing characteristics during local dish preparations (Atap). This may lead to their poor adoption. However, processing OFSP into other products may encourage farmers to adopt them.
- Embracing Extension officers from the existing traditional service is a disincentive to technology dissemination and adoption unless they are closely supervised. Farmer facilitators, with a good grasp of the technologies and approach were found to lead to better learning by the FFS.
- Rallying local stakeholder support speeds up the process of promotion and dissemination.
- Machine-sliced chips are not easily affected by storage weevils as compared to traditional manual slicing method.
- Commodity market potential is a crucial sustaining ingredient of technology reception and adoption.

Discussion

Although significant progress has been made towards promoting production, processing and consumption of OFSP varieties, there is a general need to search for more competitive markets for both roots and chips. Existing opportunities such as exportation of organic fresh roots to European Union countries avenues to supply local markets should be explored. Farmers are also encouraged to stagger their planting periods to avoid over supply during peak harvest seasons.

Research should among other tasks develop varieties that fit the traditional cooking and eating qualities of white-fleshed roots. Farmers/consumers have already reported problems with the poor fragmentation of boiled orange-fleshed chips during preparation of local dishes. Processors could investigate the potential for packing sweetpotato-cassava composite flours to increase their shelf-life so that it can be supplied to Super Markets and local shops. This would increase the level of use of OFSP flour as most potential consumers would like to avoid laborious processes of preparing local foods. OFSP varieties especially the most popular Ejumula is highly susceptible to viral infections implying that they cannot be recycled for more than three generations. Therefore arrangements should be made to replenish them with clean vines periodically.

Collective appraisal of the of approaches used by different stakeholders would probably lead to wider appreciation and advocacy for institutionalization of the FFS approach among different stakeholders both as a technology and input-based approach for agricultural-oriented communities.

Conclusions and Recommendations

- Orange-fleshed sweetpotato promotion through SP IPPM FFS has resulted in fast and effective dissemination and adoption of IPPM sweetpotato technologies.
- More initiatives are needed to widen the market opportunities and improve on prices.
- Research should focus at improving disease resistance, especially viruses and dry matter content of OFSP varieties. Opportunities to conserve vines during dry season should be encouraged to avoid continuous purchases of vines from the central region where the virus pressure is much higher.

- Follow-ups on FFS graduates and increased support to backstopping the farmer-facilitators through the farmer facilitators association to establish a sustainable technology dissemination system.
 - Policy makers should spearhead the institutionalization of the FFS approach
 - Farmer processors chipping roots should explore opportunities of acquiring soft loans from community-based credit institutions.
 - Millers should aim at composite formulations for both local and foreign markets.
 - Further sensitization on quality maintenance especially of grated products.
 - Scaling up dissemination of OFSP varieties within and outside Soroti district.
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The role of sweetpotato root and starch characteristics on thermally processed products

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Abstract. The significance of processing sweetpotato (SP) was investigated by assessing the characteristics of three new sweetpotato varieties (Tanzania, New Kawogo and Naspot 5) and a UK commercial (Jewel) variety. The characteristics of the roots (dry matter, sugar and amylase contents) and their respective starches (gelatinisation and pasting temperature parameters) were analysed. Tanzania and Naspot 5 SP root pulp had comparable dry matter (37.0-37.8%), reducing sugar (0.5%) content and alpha amylase activity (2.60-2.66 mg.g⁻¹.min⁻¹) as opposed to New Kawogo. Jewel variety had the lowest dry matter (19.0%), highest reducing sugar content (2.6%) and alpha amylase activity (7.78 mg.g⁻¹.min⁻¹). Variation in SP root characteristics might indicate post harvest changes or due to variety differences.

The same ranking order of the starch varieties was followed for gelatinisation and pasting temperature parameters, with Naspot 5 having the highest, followed by Tanzania, New Kawogo and Jewel starches. Jewel and New Kawogo similarly showed comparable onset temperatures of gelatinisation and pasting that differed from Naspot 5 and Tanzania. Naspot 5 (15.6 J/g) and Tanzania (15.2 J/g) starches exhibited higher enthalpy of gelatinisation than Jewel (13.2 J/g) and New Kawogo (12.4 J/g), indicating that they may require high energy to disrupt their crystalline granule order. Jewel SP processed products are likely to have inferior sensory properties. Individual starch characteristics did vary but may be used to select sweetpotato varieties for specific products.

Production potential of root and tubers in association with plantation crops

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Abstract. In India tropical root and tuber crops namely cassava, greater yam, lesser yam, elephant foot yam, taro, tannia and arrowroot are mostly cultivated in association with plantation crops like coconut, arecanut, coffee, rubber and banana. Intercropping the root and tubers with tree crops both at the immature and mature phases is a common practice especially in small and medium sized land holdings, in order to augment the net income and employment opportunities. In such farms, the produce from the perennials generates the cash income, while the starchy root and tubers partially meet the food requirements of the farm family and the feed needs of farm animals. Research during the past two decades in India had brought out the agronomic and economic advantages of the cropping systems involving tropical root and tubers and the plantation crops. In this paper the opportunities, challenges and future research needs of cropping/farming systems involving tropical tuber crops and perennials are critically evaluated.

Development and promotion of orange-fleshed sweetpotato varieties in Western Kenya

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Abstract. Vitamin A deficiency is a major nutritional problem in Kenya, leading to night blindness and high mortality of infants. Orange-fleshed sweetpotato (OFSP) varieties are being promoted as food based intervention to combat vitamin A malnutrition. Most of the OFSP varieties being promoted in Kenya are, however, not popular with farmers because of their poor adaptability and low root dry matter content. The only two OFSP varieties SPK004 and Zapallo with moderate consumer acceptance have not reached many farmers because of an inefficient planting material multiplication and distribution systems. New OFSP clones were evaluated at three sites in western Kenya between 2001 and 2002 in order to identify more clones with desirable characteristics. Clones 566632, 440248, 440208, 440031, Sponge, K118, and K135 were found to be promising in terms of root yield and taste qualities. Attempts were made to multiply and distribute planting material of the OFSP varieties using NGOs, community based organisations (CBOs), extension staff and farmer group partners working in area. A total of 49 million cuttings were distributed to 12,000 sweetpotato growers farmers within the two years.

Introduction

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is one of the world's highest yielding crops in terms of production per unit area, exceeding that of major cereals such as rice, and with higher food value (Woolfe, 1993). In Kenya,

sweetpotato is regarded as a "poor man's" crop because it is often grown and consumed by resource limited households and has the ability to give satisfactory yields under adverse climatic and soil conditions as well as under low or non-use of external inputs (Carey *et al.*, 1999; Ndolo *et al.*, 1998). It ranks third in importance after potato and cassava among root and tuber crops (Kung'u, 1999); however, it has become even more important in areas where cassava mosaic virus disease has devastated cassava (PRAPACE, 1998) and striga weed is a problem. As a food security crop, sweetpotato can be harvested piecemeal as needed, thus offering a flexible source of food and income to rural households that are mostly vulnerable to crop failure and fluctuating cash income. Additionally, it has a short maturity period of 3 to 5 months.

Sweetpotato is also important for human nutrition especially the orange-fleshed varieties which contain high levels of β -carotene used to combat vitamin A deficiency (Low *et al.*, 1996) in children under the age of five and breast-feeding mothers. Until very recently, relatively little emphasis was placed on OFSP varieties by researchers since farmers in Kenya were not used to the orange colour in sweetpotato. The scenario, however, changed after farmers realized that the OFSP varieties have higher food value in the form of β -carotene than the white or yellow types.

Earlier experiments in Kenya led to the identification of two OFSP varieties SPK004 and Zapallo which were fairly acceptable to farmers. However, Zapallo was later rejected

by many farmers because of its low root dry matter and its inability to withstand drought and high sweetpotato virus diseases. There was therefore a need to identify more OFSP varieties with acceptable agronomic and root qualities. Lack of well-organized seed distribution system for the vegetatively propagated crops in Kenya has also contributed to the slow rate of dissemination of the new varieties. New varieties are traditionally disseminated through farmer-to-farmer variety exchange and a limited sale of cuttings in the markets at the onset of the planting season. The objectives of this study were to involve farmers in the identification of new OFSP varieties and to use the existing NGOs, CBOs and farmer groups in the promotion of the varieties.

Materials and Methods

Identification of varieties. Two variety selection trials were conducted in Kenya between 2001 and 2002. The first trial consisted of OFSP clones introduced from other parts of the world through the International Potato Centre (CIP) while the second trial was made up of local OFSP cultivars collected from farmer's field in western Kenya.

Thirteen to 18 exotic OFSP clones were evaluated at KARI-Kakamega, Agolot village and Alupe sub-centre in western Kenya. KARI-Kakamega is situated in the Upper Midland one (UM1) agro-ecological zone at an altitude of 1585 m above the sea level and with annual rainfall of 1900 mm. The soils are well-drained, deep friable clay with humic topsoil (mollic nitosols) developed on tertiary or older basic igneous rocks. Agolot is located in Busia district at an altitude of 1220 m above sea level with a mean precipitation of 1790 mm. The soils are well-drained yellowish brown friable clay over petrolinthite (orthic ferralsols). Alupe is located at an altitude of 1250 m above the sea level and consists of moderately well drained, shallow, brown to dark brown soils over petro-plinthite (murram cuirass soils).

The clones were planted in a randomized complete block design with three replications. Each plot consisted of four ridges 4.5 m long and 100 cm apart. Each ridge was planted with 15 cuttings, 25-30 cm in length at a spacing of 30 cm between plants. The trial at Agolot was managed by the farmers in collaboration with Ministry of Agriculture extension staff and Rural Energy Food Supply Organization (REFSO), an NGO operating in the area. The trials at Alupe and KARI-Kakamega were managed by researchers but farmers from the surrounding were invited to evaluate the clones at harvest. Data were collected on virus infection using a scale of 1 to 5, where, 1=no virus attack and 5=severe virus infection. Reaction to drought was also assessed using a 1 to 5 scale, where 1=very susceptible to drought and 5=very resistant/tolerant to drought. At harvest, vines were cut at 10 cm above the ground and weighed. Storage roots were lifted and separated into marketable and non-marketable sizes. Marketable roots were those with cross sectional diameter at the largest portion of the root above 3 cm. The sum of marketable and non-marketable roots formed the total storage root yield. Dry matter content of roots was determined by oven drying a 200g-root sample for 48 hours. Five roots of each clone were cooked and evaluated by farmers using a score of 1 to 5, where 1=very poor taste and 5=excellent taste.

The second experiment consisting of seven local OFSP varieties was conducted for two seasons at Alupe sub-centre and KARI-Kakamega. Varieties were grown in 4.5-m plots of four rows, 100 cm apart. Cuttings were planted 30 cm from each other. The varieties were randomized within the blocks and replicated three times. Data were taken on virus infection, fresh weight of vines, storage root yield and dry matter contents of roots as described in the first trial.

Results and Discussion

Analysis of variance showed that there was significant site x variety interaction in all

parameters measured. Mean root yield was highest at KARI-Kakamega followed by Alupe. The high root yield at Kakamega was attributed to the high rainfall received during the trial period. Agolot had the poorest root yield as a result of the black cotton soil which compacted during the dry season and restricted the expansion of roots. Total root yields at Kakamega (Table 1) ranged between 15 and 49 tons/ha. Varieties 566632, 440248, 440208, 440031, 420014 and 440060 had higher root yield and dry matter content than the check variety Zapallo. All the best clones had acceptable root taste except for 440208. Although clones 566632, 440208 and 440060 had promising root yields, they were found to be susceptible to drought. Performance of the sweetpotato clones at Agolot is given in Table 2. The best clones at the site were 420094, 400014, 420054 and 400013. The results at Alupe (Table 3) showed that although clones 440208, 420009, 566632, 420094, 420001,

420286, 440248 and 420014 performed well, they were not significantly superior to Zapallo in terms of root yield. The dry matter contents of roots were higher than at Kakamega.

Mean performance of the local orange-fleshed varieties at Kakamega and Alupe was low compared to the exotic varieties (Tables 4 and 5) suggesting that the local accessions were either harvested before attaining their maximum maturity or they just have lower yield potential than the introductions. Varieties K44, K135 and K52 gave 17.1, 14.1 and 13.5 tons/ha of roots at Kakamega compared to 11.6 tons/ha obtained from SPK004 while none of the local varieties performed better than SPK004 at Alupe.

Promotion and dissemination of orange-fleshed varieties. While the selection of new orange-fleshed varieties was going on, researchers, extension staff, NGOs, CBOs and farmers' groups were involved in the

Table 1: Mean performance of exotic orange-fleshed varieties planted at KARI-Kakamega for two seasons.

Entry		Total root yield t/ha	Foliage wt T/ha	Virus score (1-5%)	Taste score (1-5)	Reaction to drought (1-5)	% DM
566632	-	49.2	25.4	2.3	3.3	2.4	23
440248	-	44.7	19	3	2.6	2.7	19
440208	Serenta	40.8	22	3.2	4	3.2	29
440031	-	36.9	14	3	3.6	3.4	27.3
420014	Jonathan	21	23.9	2.7	4.5	3.2	28.2
440060	TIB 4	21.9	10.2	2	2	2.6	27.2
440255	SP 094	21.4	13.4	4.3	3.5	3.3	19
440286	Bei jieng 553	22.5	15.4	3.6	3	3.7	25
420027*	Zapallo	20.2	23	4.3	2.9	2.5	14.5
LO-86-33	-	17.5	36	3	3	3.4	17.9
400014	Comote amarillo	16	33.6	3.2	4	3.6	22
420054	-	16.9	34.5	3.6	2	2.2	25.6
420009	Japanese	18.3	23.6	2.9	2.5	2.4	20.5
420094	Huanchano	15	14	3	2.9	2.6	29
187017	Salyboro	14.6	18.9	1.2	2	4	33.2
Mean		25.1	21.8	3	3.1	3	
LSD (0.05)							
CV %		9.4	10.8	0.8	0.6	0.7	
		33.6	41	14.3	20.4	19.7	

*Check

Table 2: Mean performance of orange-fleshed varieties planted at Agolot (Busia).

Entry		Total yield t/ha	No. of roots/plant	Foliage wt t/ha	Virus score (1-5)
440284	BIS 192	8.1	3	7.9	2.3
420001	Anaranjo itende	8.1	4	7.2	1.7
420094	Huanchano	12.1	4.7	15.7	1.7
440286	Bei jieng 553	8.1	1.3	6.7	1.3
400014	Comote amarillo	14.8	4	7	2.3
420054	-	9.6	3.2	9.2	1.3
440208	Serenta	7.5	4.9	3.8	3
420006	-	6	3.9	8.9	1.2
420019	Pedro	5.7	3.6	13.8	1.3
420005	Nemanete	6.4	3.8	7.3	2
400013	100092	9.3	4.7	8.1	2
420014	Jonathan	4	3.8	4.3	1.3
440151	LA10 44	6.4	3.9	9.4	1
Mean		8.2	3.8	8.4	1.8
LSD(0.05)		3.6	2.3	3.2	1.7
C V %		26.6	36.6	23	56.5

Table 3: Mean performance of exotic orange-fleshed varieties at Alupe sub-centre in western Kenya.

Entry	Total yield t/ha	Foliage wt T/ha	Virus score	Taste score (1-5)	Reaction to drought (1-5)	% DM (1-5)
440208Serenta	22.1	19.5	1.3	3.6	3	29
420009Japanese	21.9	29.6	2	3.2	3.3	26.2
566632 -	20.3	17.4	1.7	3.5	2.8	24.6
420094Huanchano	19.9	44.4	1.6	2.9	2.7	29.8
420001Anaranjo itende	19.4	20.2	2	3	2.9	27.6
440286 -	19.3	11.9	2	3.3	3.1	30
440248Jonathan	19	24.5	1.9	4	3.9	25.8
420014Zapallo	18.4	41.2	1.3	2.6	3.2	25.4
420027SP 094	17.9	15	4	2.4	1.6	17.6
440255 -	16.3	35	3.7	2.6	3.5	33.6
440031 -	15.2	29.3	3.9	3	3.5	26.8
440091Kafr El-layat No 1	13.3	26	4	3	2	25
440047Bugs buny	11.3	23.1	2	3.4	2.2	22.7
420054 -	7	14.1	2.3	3.2	2.6	28.9
187017Salyboro	8.7	56	1.2	3.5	2.7	30
440015 W-220	5.8	29.6	2.1	2.9	2.1	28
420005Nemanete	8.2	36.6	2.3	2.8	3.9	29.7
420019 Pedro	3.6	22.2	3	4	3.7	22
Mean	11.4	14.9	27.6	3.2	2.9	26.8
SED+	4.2	5.2	7.1	0.6	0.4	5.6
C V %	35.2	32.7	31.7	15.8	15.6	22

Table 4: Mean performance of local orange-fleshed varieties planted at Alupe sub-centre in western Kenya.

Entry	Total yield t/ha	Foliage wt t/ha	Virus score (1-5)	Taste score (1-5)	DM%
K118	15.7	36.9	1.7	4.5	26.8
K135	14.4	36.7	2	4	30
K207	1.5	52.9	1	3.6	29.3
K37	12.4	41.9	2.3	4	34.2
K44	4.4	41.2	1	4.2	29.8
K52	12.5	35.5	2.3	4.3	31.9
SPK004*	23	50	1	3.8	29.9
Sponge	13	47.4	2	4.5	32
Mean	12.1	42.8	1.7	4.1	
SED+	2.8	6.8	0.5	0.7	
CV %	28	19.5	12	15.6	

Table 5: Mean performance of local orange-fleshed varieties planted at KARI- Kakamega during 2001 and 2002 seasons.

Entry	Total yield t/ha	Foliage wt t/ha	Virus score (1-5)	Taste score (1-5)	DM%
K118	11.7	41	2.3	4.1	29
K135	14.1	36.1	3	3.9	31.3
K207	0.9	43.1	4	3.7	29.8
K37	1.3	39.4	4	4.2	30.2
K44	17.1	47.5	1.6	4	28.7
K46	8.8	40.3	2	4.2	30.3
K52	13.5	50	2.2	3.9	30.5
SPK004*	11.6	38.9	1.7	3.8	33.4
Sponge	6.1	48.1	3		
Mean	9.5	42.7	1.6	4	
SED+	3.5	9.1	0.6	0.5	
CV %	34.4	26	23.2	17.3	

promotion and dissemination of the existing orange-fleshed varieties to farmers. The NGO and CBO partners were selected from those already involved in agricultural activities. The main NGOs involved in seed multiplication and promotion of the orange-fleshed varieties are given in Table 6. The dissemination process of the OFSP varieties in western Kenya started with the on-farm selection of the varieties by the farmers. The selected varieties were bulked in primary multiplication sites at KARI-Kakamega, Alupe sub-centre, Yala swamp and Siaya FTC in western Kenya. Sweetpotato cuttings from these sites were

used by the partners to establish decentralized secondary seed multiplication units close to farmers. Planting materials from the decentralized seed bulking units were distributed to the group members or their neighbours either freely or at a cost. Some planting material from these plots were also purchased by other organizations and used to establish more secondary multiplication plots in other parts of Kenya. The amount of OFSP cuttings distributed to farmers by the different stakeholders is given in Tables 6 and 7. A total of 49 million cuttings covering 2700 hectares of land were distributed to farmers

Table 6: List of NGOs and CBOs partners involved in the promotion of orange-fleshed sweetpotato varieties in western Kenya.

Name of NGO	Operation areas (Districts)
Resource Project Kenya (RPK)	Vihiga
Christian Partners Development Agency (CPDA)	Vihiga
Africa Now	Vihiga, Kisumu
Ugunja Community Resource Centre (UCRC)	Siaya
Rural Energy Food Security Organization (REFSO)	Busia, Teso
Appropriate Rural Development Agricultural Programme (ARDAP)	Busia
Catholic Relief Services (CRS)	Migori, Rachuonyo
Rural Farm Alternatives Organization (RUFAO)	Bungoma
Community Research in Environment and Development Initiatives (CREADIS)	Bungoma
Akukuranut Development Trust (ADT)	Teso
International Christelijk Steunfond Africa (ICS)	Busia, Teso

Table 7: Number of the cuttings distributed and area planted in each district in western Kenya.

District	Amount of cuttings distributed x 10 ⁶	Area planted(ha)
Busia	13.0	680
Kakamega	6.8	340
Bungoma	3.1	150
Lugari	2.0	110
Teso	8.0	400
Vihiga	8.2	410
Butere/Mumias	2.7	200
Siaya	5.2	350
Kisumu	1.0	70
Total	49.1	2710

during the reporting period. The highest amount of planting material was given to Busia district as it had more NGOs involved in agricultural activities compared to other districts. A total of 102,000 households consisting of 511,000 people benefitted from the orange-fleshed varieties (Table 8).

In order to sustain seed multiplication efforts, partners were trained on the rapid multiplication techniques of planting materials (using 2-node cuttings; beds) and for maintaining them (plantings in well watered areas or in shaded areas near households). Efforts were also made to identify farmers with access to swamps or other permanently well-watered locations to serve as suppliers (in drier areas, presumably sellers) of planting

material. Quality of planting material was maintained through rejuvenation of multiplication plots with virus free planting material obtained from CIP, Muguga and rapidly multiplying these using tissue culture technique at KARI-Kakamega.

Promotion of OFSP varieties and their nutritional benefits was also done through agricultural shows, farmers' field days, from which participants departed with samples of cuttings to plant. Efforts were also made to use field schools or formal training institutions to popularize orange-fleshed varieties to the farmers and consumers. Attempts were also made to include ministry of health staff and village birth attendants in the promotion of the OFSP varieties.

Table 8: Number of households and beneficiaries of the orange-fleshed varieties in western Kenya.

District	Number of households	Number of beneficiaries
Busia	16400	82000
Kakamega	19000	95000
Kisumu	8740	43700
Siaya	6300	31500
Bungoma	7700	38500
Lugari	10600	53000
Teso	8800	44000
Vihiga	18000	90000
Butere/Mumias	6700	33500
Total	102,400	511,200

The approach also placed strong emphasis in training partners and farmers on sweetpotato utilization and nutrition including production of various sweetpotato-based products such as chapatis, chin chin, donuts, mandazis, juices, crackies, and weaning diets. Some members of the groups are already involved in commercial production of OFSP products. Training efforts in post-harvest utilization and nutrition have stimulated high interest among farmer groups on the orange-fleshed varieties. Participating NGO and CBO partners were used as trainers and models for the expansion of activities to other locations through training exercises and exchange visits.

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On-farm trials on long-term storage of sweetpotato at Gezaulole village, Kigamboni, Tanzania

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Abstract. The influence of store design on farm pre-treatment, storage site, type of soil and the nature of storage place (shade) on sweetpotato storage was assessed at Gezaulole village near Dar es Salaam, Tanzania. The design of the store had an influence on the storability of the fresh sweetpotatoes. Recovery of marketable tubers stored in pits constructed under shade was significantly higher ($P < 0.05$) than that from clamps. Preharvest pruning had no influence on the recovery of marketable sweetpotato tubers.

Effect of altitude and plant age on cyanogenic potential, dry matter, starch and sugar content in cassava genotypes

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Abstract. A study was conducted at three locations in Uganda (Bulisa: 650 m asl; Namulonge: 1150m asl and Kapchorwa: 1750 m asl) to evaluate the effect of altitude on dry matter, starch and sugar content, and cyanogenic potential in cassava. Ten genotypes from five different sources were used in a randomized complete block design with three replications, and data were repeatedly measured at three month intervals up to 15 months after planting. The mixed model analysis indicated significant ($p < 0.001$) differences among genotypes at each elevation for dry matter production. Significant interaction between plant age and source and between genotypes within source and plant age at all elevations indicated genotypic differences among sources as well as among genotypes within sources in production and partitioning of assimilates. The study indicated that dry matter content was higher at high altitude than at low and mid altitude. Highly significant ($p < 0.001$) differences for CNP were also observed between sources and among genotypes within source at mid altitude. Plant age effect was significant for CNP. Significant ($p < 0.001$) interactions between plant age with source and with genotypes nested within source indicated that genotypes as well sources produced different amount of CNP during plant growth cycle, obtaining high levels at all elevations at around six months after planting. The study also showed that starch and sugar contents were high at higher altitude than at low and mid altitude. A similar trend was observed with dry matter content.

Development and promotion of sweetpotato products in Western Kenya

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Abstract. Sweetpotato utilization in western Kenya has for along time been limited to boiling, roasting and chewing raw. In order to add value to the crop, attempts have been made to process sweetpotato into different products. Several products were prepared among them ‘crackies’, ‘*mushenye*’ Amaranthus relish with sweetpotato flavour and sweet potato juice. These products were evaluated by extension agents for acceptability. The most highly ranked products were ‘crackies’ made from sweetpotato and cassava flour, ‘*mushenye*’ made from sweetpotato variety *Mugande* and juice from the orange-fleshed sweetpotato variety SPK004. Amaranthus relish with sweetpotato flavour was more preferred to amaranthus with Roiko or soya flour flavour. The study also showed that products with a combination of sweetpotato and cassava flour were more preferred to pure wheat products. Currently the selected products are promoted through field days, shows as well as individual and group training involving different technology transfer agents such as NGOs and community based organizations. The study showed there is high potential for sweetpotato products utilization in home consumption.

Introduction

Sweetpotato (s/p) is the world’s seventh most important food crop after, wheat, rice, maize, potato, barley, and cassava (CIP 1996). Domestic supply through production of sweet potatoes indicates that it is third besides

maize and cassava in calorie output (FAO 1992-94). It is an important staple food in Kenya, utilized by most households and as described by Hagenimana *et al* it is a woman’s crop and available all year round (Hagenimana *et al.*,1999). Therefore sweetpotato has the potential of bridging the food gap due to diversified processing and utilization technologies that have been produced but not yet fully exploited. The color intensity of the sweetpotato root flesh differs from one cultivar to another and varies from white to deep orange. The intensity of the color is attributed to carotenoid content (Ameny and Wilson 1997). A study on carotenoid content in fresh, dried and processed sweetpotato showed that increased consumption of orange flesh sweetpotato in either fresh or processed form can contribute in alleviating dietary deficiency of vitamin A (Hagenimana *et al.*,1998) Consumption of sweetpotato in Western Kenya is mainly in raw, boiled or roasted. Storage practiced is in-ground and only harvested when need for consumption or sale arises. The International Potato Center (CIP) and Kenya Agricultural Research Institute (KARI) developed technologies using sweetpotato in three forms, (boiled and mashed), (grated) and (flour, mixed with 30% to 50 % wheat flour) these were acceptable to consumers. However recent survey indicates that the products were expensive due to inclusion of wheat flour. This paper describes development and promotion of cheaper products by replacing wheat flour with cassava flour. Consumers also requested skills in juice and spicy food additives.

Products were made, tested and evaluated for general acceptability. The best options were selected, improved, tested and evaluated again and then replicated on-farm. Data was collected and analyzed and most acceptable products transferred to farmer groups and extension agents through demonstrations. Groups and individuals interested in micro enterprise were given skills in simple product making, packaging and promotion.

Materials and Methods

Ideas concerning improvement of old products and new products were generated and tried out at KARI laboratory. Participatory interactive methods were used to transfer skills in product production and promotion to extension, farmer groups and , Non Governmental Organizations (NGOs)/ Community Based Organizations (CBOs) agents. This study was done on the following products: juice, mshenye, crisps, crackies, chapatti, mandazi, onion bites and sweetpotato flavour.

Fresh sweetpotato juice made from three sp varieties (SPK 004 orange flesh and high in Vitamin A, Mugande white flesh and liked for marketability and Bungoma cream flesh and popular with farmers). The roots 600g of each variety were peeled, washed, boiled and mashed. For each variety, 500g of mash and 2000ml of water were mixed and sieved. The result content for each variety was 1800ml and divided in three for the following treatments:

SPK004 plain
SPK004 + sugar
SPK004 + sugar + lemon juice
Bungoma plain
Bungoma + sugar
Bungoma + sugar + lemon juice
Mugande plain
Mugande + sugar
Mugande + sugar + lemon juice

Test panel at KARI lab evaluated and eliminated the first two treatments for each variety and recommended the last treatment

for each variety for on-farm test. Farmer groups and extension staff carried out on-farm tests.

S/p crisps. 18 medium roots from three varieties of sweetpotato (SPK 004, Mugande and Bungoma) were washed, peeled, washed again and sliced into very thin pieces using a kitchen grater. The contents were separately put in salted water, drained and deep fried till starting to brown. The crisps were removed from oil, salted and let to cool. The crisps were tested, evaluated and recommended for on-farm tests, which were done.

S/p “mshenye”. 9 medium roots from three varieties (SPK 004, Mugande and Bungoma) were washed, peeled, washed again, sliced and boiled. 600g of pre-boiled maize and beans was divided in three portions of 200g and added to each variety of sweetpotatoes and mashed. Salt was added to taste and the product tested and evaluated for variety and recommended for on-farm tests.

S/p Crackies. Wheat flour (Unga Millers Ltd. Nairobi) 400g and soya flour 50g for crackie1, S/P flour 200g, wheat flour 200g and soya flour 50g for crackie2, S/P flour 150g, cassava flour 250g and soya flour 50g for crackie3 was weighed and put in three mixing bowls. Baking powder (Kapa Oil Refineries) 10g and cayenne pepper 10g (Ruby Industries - Nakuru) were sieved into the flour, iodized salt 3g (Kensalt Nairobi) was sprinkled on each mixture. Bahari oil 20g (Bidco Oil Refineries Ltd. Thika) were added. Rub-in method was used to mix the ingredients. An egg was broken, poured in a cup, checked, and then added to the mix. A cooking stick was used for a while to turn in the egg then rub-in method resumed. A little warm water was added to soften the dough. Kneading was done by hand till the required texture of elastic smooth dough was formed. The dough was left to relax while cooking oil was poured into a pan and put on the Kenya Ceramic Jiko (KCJ) to heat. The dough was packed into the noodle machine and the handle of the machine turned clockwise to

extrude the contents. The dough contents were dropped into the hot oil and let to brown while turning with a perforated flat long spoon. After attaining golden brown color, the contents were removed and drained put in plastic buckets and left to cool, tested, evaluated and recommended for on-farm.

S/p chapati Wheat flour 400g and soya flour 50g for chapatti 1, S/P flour 200g, wheat flour 200g and Soya flour 50g for chapatti 2,. S/P flour 150g, cassava flour 250g and soya flour 50g for chapatti 3 was weighed and put in three mixing bowls. 50g of oil and 5g of salt were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowls and kneaded till stiff smooth paste was formed. The dough was divided into 8 equal balls and rolled on a floured surface. Each ball was folded to form a strip and coiled to form a circle and put aside for 20 minutes. Each coil was rolled out into a thin circular sheet and shallow fried on both sides till golden brown. The product chapatti, was tested, evaluated and recommended for on-farm.

S/p mandazi. Wheat flour 400g and soya flour 50g for mandazi 1, S/P flour 200g, wheat flour 200g and soya flour 50g for mandazi 2,, S/P flour 150g, cassava flour 250g and soya flour 50g for mandazi 3 was weighed and put in three mixing bowls. 20g of oil, 40g sugar and 10g of baking powder were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowl s and kneaded till smooth paste was formed. The dough was rolled on a floured surface to 1cm thickness. A knife was used to cut uniform square pieces, which were deep fried till golden brown. The mandazi products, were removed from oil, drained, cooled, tested, evaluated and recommended for on-farm.

S/p onion bites. Wheat flour 400g and soya flour 50g for onion bites1, S/P flour 200g, wheat flour 200g and soya flour 50g for onion bites 2,, S/P flour 150g, cassava flour 250g and soya flour 50g for onion bites 3 was

weighed and put in three mixing bowls. 20g of oil, 10g salt, 5g of chilli powder, 10g chopped spring onion and 10g of baking powder were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowl s and kneaded till a soft smooth paste was formed. The dough was cut into small balls that were deep fried till golden brown. The products were removed from oil drained, cooled, tested, evaluated and recommended for on-farm.

Sweetpotato flavour was made by extracting 300g starch from white sweetpotato roots. The starch was divided into three portions of 100g and given three treatments as follows: **1.** Spices 70g, Sugar 20g, salt 10g, **2.** Spices 40g, Sugar 40g, salt 10g, **3.** Spices 20g, Sugar 60g, Salt 10g. The spices were added to amaranthus relish, tested and evaluated. The first and third were eliminated and recommendation given to use the second lot. The selected lot was taken on-farm and compared with soya flour and roiko mix which is a commercial flavour

Promotions. Product testing and promotion was done through several channels as follows: On-farm demonstrations and trainings to farmer groups, NGOs/CBOs, displays, tasting/lectures at agricultural shows, schools, farmer field days and on- site training to Ministry of Agriculture extension.

Results and Discussions

The sugar and lemon juice addition in the sweetpotato juice made the product highly acceptable as compared to when the product was plain or only sugar was added (Table 1). The evaluators compared juices with three commercial varieties of 'Fanta' soft drink. The test of SPK004 was likened to 'Fanta' orange, Bungoma to 'Fanta' passion and Mugande to 'Fanta' citrus.

Overall SPK 004 variety was more preferred in the products than the Mugande and Bungoma variety (Table 2). The colour of SPK004 made the juice more appealing than

Mugande and Bungoma. The high dry matter content in the Bungoma variety and its yellow colour made it more popular for crisps. The Bungoma crisps were firm while the SPK004 were brittle. Mugande had highest sugar content which made it ideal for the *mshenye*. The second treatment of sweetpotato, wheat and soya is generally more preferred than the other two (Table 3). Chapati, mandazi and

onion bites required wheat flour this is due to the their soft texture. Crackies have entered the snack market in all districts involved in s/p activities due to the long shelf life of four months as compared to the other three that have shorter shelf life of three to four days. Sweetpotato flavour was comparably well accepted like the commercial roiko.

Conclusion and way forward

Products produced and promoted were well accepted showing that sweetpotato has a potential for substituting wheat in high percentages. Diversified sweetpotato utilization has an indication for improving food security and local household incomes of the region.

Markets and machines are identified and farmers informed. Collaborators like NGOs are involved with farmer mobilization and machines acquisition and this is intended to help expand production and utilization of sweetpotato products.

Table 1: KARI panel fresh sweetpotato juice acceptability evaluation (N=20).

SPK004 plain	-
SPK004 + sugar	1
SPK004 + sugar + lemon juice	19
Bungoma plain	-
Bungoma + sugar	1
Bungoma + sugar + lemon juice	19
Mugande plain	-
Mugande + sugar	1
Mugande + sugar + lemon juice	19

Table 2: On-farm acceptability of products made from three varieties of roots (N=30).

Products	SPK 004	Mugande	Bungoma
Juice	20	5	5
Mshenye	10	15	5
Crisps	2	5	18

Table 3: On-farm acceptability of products made from combinations of flour (N=30).

Products	Wheat+ soya	S/P+wheat+soya	S/P+cassava +soya
Crackies	1	10	19
Chapati	8	18	4
Mandazi	10	14	6
Onion bites	4	16	10

Table 4. On-farm acceptability of sweetpotato flavour (N=30).

S/p flavour	12
Roiko	13
Soya flour	5

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Successful restoration of cassava production in Western Kenya

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Abstract. Cassava is an important staple food for consumption and income generation for farming communities in Western Kenya. The region grows and consumes 60% of the national cassava production. Between the years 1994 – 1995 a virulent form of cassava mosaic disease devastated all traditional cassava varieties. Production and productivity of the crop completely declined. Yield loss incurred in 1998 due to CMD was estimated at 15,000 tons valued at US\$ 10 million. In response to the magnitude of the problem, Kenya Agricultural Research Institute (KARI) collaborated with International Institute of Tropical Agriculture to mitigate cassava mosaic disease and other important agronomic characteristics. Fifteen desirable clones were bulked for seed through a three-tier multiplication scheme (primary, secondary and tertiary) to ensure equitable, fast and sustainable distribution of healthy planting materials. The clones which are multiplied and distributed were: SS4, Migyera, MM96/5280, MM96/1871, MM96/4466, MH95/0183, MM96/7688, TME – 14, MM96/4884, MM96/3868, MM96/9308, MM96/4684, Unknown 2, MM96/7151, MM96/9362. Over 34 million stems from primary sites have been distributed to farming communities. The coverage under improved cassava is approximately 13,000 ha., which is 38% restoration of the crop. Over 300,000 households are growing improved cassava in Western Kenya. Fresh cassava tubers and processed cassava products are now available on local and urban markets in the region.

Hunger, famine and poverty have been addressed by successful restoration of cassava production in Western Kenya.

Introduction

Cassava (*Manihot esculenta* Crantz) is a major source of dietary energy for a large population in tropical Africa. It enhances household food security and is a source of income. It provides livelihood to 100 million people globally (Legg, 1999). In Kenya, cassava is grown in Western, Eastern/Central and Coastal regions. The crop provides 9% of the total calories in the diet of Kenyans (Republic of Kenya, 1990). Western region of Kenya grows and consumes 60% of national cassava production. In many districts of Western region of Kenya, cassava is the staple food crop. Cassava is mainly grown in intercropped with beans, maize and bananas.

Cultivation and production of cassava crop in the region is constrained by biotic and abiotic factors. Non use of healthy planting materials, and improved agronomic practices and limited range of improved processing technologies affect production of the crop. The most devastating abiotic factor in the recent years is cassava mosaic disease. In Nyanza, yields declined from 6 - 3 tons of fresh tubers. In Teso district, the area under cassava production reduced to 1000 ha. from 3000 ha. annually (MOA and RD) Annual Report 1997/1998). Yield loss experienced in 1998 due to CMD was estimated at 150,000

tons valued at US\$ 10 million.(IITA Annual Report 1998).

Considering the implications of the disease it became extremely necessary to halt spread of the pandemic. Intervention measures that were considered essential to mitigate the scourge were introduction and evaluation of germplasm for resistance to ACMD and other agronomic characteristics. Cassava clones which were desirable, adaptable and acceptable were rapidly multiplied and distributed to the farming communities in Western Kenya (Project Report 2001/2). This paper describes steps which were adopted to restore production of cassava in Western Kenya.

Materials and Methods

The study was implemented by multiple stakeholders. These included KARI, IITA, extension personnel of the Ministry of Agriculture, Non-governmental organizations, Community based organizations, farmer groups, civic leaders and administrators. The approach used was participatory involved a series of targets that are logically circular and potentially recycling of basic activities – diagnosing the problem, identifying solutions, testing and adopting the technology while incorporating farmers' evaluation of the technology. Awareness forums and intervention measures spelt out partner roles. The following activities were carried out:

(a) Monitoring and diagnostic surveys. Surveys were conducted in the Lake basin region to track the progress of the pandemic from 1995-2002.

(b) Germplasm introduction and evaluation. A large number of cassava germplasm were introduced into Kenya. These materials were evaluated for resistance to CMD. Promising materials were advanced through preliminary and advanced yield trials and adaptability trials on-farm in different agro-ecological zones. In addition to diseases and pests these

clones were also evaluated for yield potential, cyanogenic and dry matter content.

(c) Multiplication. The project ensured that farmers in the region obtained sufficient healthy planting materials of improved, high yielding varieties which were also resistant to cassava mosaic disease (CMD). A three-tier multiplication system was adopted. This included bulking the materials at primary sites on institutional farms, then at secondary sites organized and managed by district steering committees and tertiary sites which were organized and managed by NGOs and CBOs in the region. Individual farmers were also involved in multiplication at tertiary level. The system aimed at decentralising the seed delivery system to ensure that all farmer groups got seed.

(d) Trainings. Technical information on cassava production was disseminated through awareness creation sessions, trainings, demonstrations, field days, workshops and stakeholder meetings.

(e) Monitoring and evaluation. Various fora were put in place to ensure broad participation for efficient and effective implementation of the project. This included establishment of regional steering committees, National steering committee and district steering committees. The committees ensured that work-plans were followed.

Results and Discussions

Monitoring and Diagnostic Surveys. Diagnostic surveys revealed that CMD disease was spreading from Uganda into Kenya at a rate of 40 km per year (Gibson *et al.*, 1996). The disease now covers the whole region up to the boarder of Kenya and Tanzania. The approach adopted was to introduce improved varieties in areas where the disease had already devastated the crop and in areas threatened by the disease. Infection rates on cassava in Busia, Teso, Bungoma and Siaya were between 75% and

Table 1: Summary of diagnostic survey of CMD status (years 2001 and 2002).

Year	Province	Cutting infection incidence	Whitefly infection incidence	Total	Severity ¹
2001	Western	55.1%	2.1%	57.2%	3.1
	Nyanza	41.6%	1.3%	48.9%	2.7
	Mean	48.4%	4.7%	53.1%	2.9
2002	Western	4.5%	3.8%	49%	2.8
	Nyanza	51.4%	3.0%	54.4%	2.7
	Mean	48.3%	3.4%	51.7%	2.75

100%. Spread was largely by cuttings though large swarms of whiteflies were evident. Disease severity was almost maximum in most areas. The infection rate in Butere, Mumias, Kakamega and Vihiga during the same period of was between 65% and 70%. Further to the south in Kisumu and Nyando districts infection ranged between 30% and 50%.

Data from the most recent surveys (year 2001 and 2002) revealed that CMD disease pressure has declined. Total infection was compared to low in Western province than Southern Nyanza (Table 1).

Germplasm and exchange and evaluation.

Since 1997 a total of 1408 cassava germplasm have been introduced into Kenya. In 1998, two clones, SS4 and Migyera were released for multiplication and distribution to the farming communities. In the year 2001, thirteen more clones were released for multiplication and distribution. The clones were; MM96/5280, MM96/1871, MM96/4466, MH95/0183, MM96/7688, TME-14, MM96/9362, MM96/7151, MM96/4884, MM96/3868, MM96/9308, MM96/4684 and unknown 2. All these are resistant to cassava mosaic disease (CMD), over 20 tons/ha under farmers management. They are also early maturing (taking between 12-14 months) and are preferred for cooking, culinary purposes and flour milling.

3. Rapid multiplication and distribution.

Multiplication of selected materials was conducted. Currently the area under improved cassava clones is 13,000 ha. which is 38% restoration of cassava in Western Kenya. Over 300,000 households grow these improved cassava varieties.

4. Capacity building. Over 3,000 farmers and agricultural workers have been trained in all aspects of cassava production and control measures of CMD, rapid multiplication of CMD free planting materials, processing and utilization. The efforts were aimed at making cassava production sustainable in the region.

Summary

Monitoring and diagnostic surveys, germplasm introduction, three tier multiplication and distribution arrangements and capacity building of the agricultural workers have proved to be a successful technology transfer method against the CMD pandemic in Western Kenya. It has enabled rapid multiplication and distribution of large quantities of improved CMD resistant varieties to many farmers in a relatively short period. Cassava growing has been restored in Western Kenya.

Acknowledgments

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Orange-fleshed sweetpotato as a disaster mitigation crop in war- torn Northern Uganda

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Abstract. In the war-torn northern Uganda, the regional potato and sweetpotato Improvement Network for East and Central Africa (PRAPACE), the International Potato Centre (CIP) and the National Agricultural Research Organization (NARO) worked with the James Arwata Foundation (JAF), a local NGO initiated in 2002, and other partners to mitigate war-related famine that is threatening about 53,000 internally displaced households. For this noble collaborative effort, orange-fleshed sweetpotato varieties Kakamega and Ejumula were used to provide the much-needed vitamin A and bolster food security in the region. Sweetpotato proved to be an effective famine mitigating crop in war- torn areas and the intervention supplied about 60 tons of food (roots) to internally displaced people living in camps in Apac, Lira and Gulu districts. Participating local farmers earned over US\$12,000 from sale of vines within a short period in 2002. This paper therefore narrates experiences with people in war- torn northern Uganda, and analyses the potential of sweetpotato to mitigate disasters.

Introduction

Northern Uganda has been a central stage of insurgency for almost two decades now; a calamity that has left over one million people displaced and living in protected camps. Due to security concerns internally displaced people (IDP) cannot attend to their farms except for a few hours each day, when there is

assured security. This restricted opportunity for the IDP to work and the displacement itself has resulted in serious food and income shortages. Government in collaboration with other relief agencies has responded by providing food relief directly to the affected families. Most often, the food supplies are inadequate in meeting daily dietary requirements and some times they are cut off due to lack of safe passage to camps because of sporadic outbreaks of fighting. To cope with the food scarcity situations, people particularly women, have always risked their lives and sneaked out of the camps to work in their fields.

Sweetpotato is an established part of the diet of rural people at risk (Tanganik *et al.*, 1998) of Vitamin A deficiency, particularly children. It is grown in areas where other sources of vitamin A, Such as oil palm and carrots are not common. Sweetpotato also plays a key role for households disrupted by HIV/AIDS and other crises (Andrade and Ricardo, 2002; Andrade and Ricardo, 2003). In northern Uganda, sweetpotato has been preferred because, among others, farmers know that it is hardy enough to thrive under rugged conditions easy to establish, requires no or minimum care and produces sufficient quantities of food for the household in a short time of about 3-4 months. Farmers have also realized that unlike cassava sweetpotato is not easily looted by the roaming hungry rebels. Introducing orange-fleshed sweetpotato varieties provided an extra

opportunity of fighting vitamin A related malnutrition among the war-affected persons in Northern Uganda (Kapinga *et al.*, 2003). This paper therefore analyses the potentials and opportunities of sweetpotato, particularly orange-fleshed types in mitigating famine and malnutrition rife in war affected communities of northern Uganda. It narrates experiences of using orange-fleshed sweetpotatoes to feed war-affected people in Northern Uganda.

About James Arwata Foundation (JAF).

Initiated in early 2002, JAF is a community-based organization that aims at transforming human mind for improving socio-economic living conditions of the marginalized groups to avert feelings of apathy. Acting as a civil society organization, JAF gives light direction and links marginalized groups to various innovations or appropriate technologies, markets, and other service delivering national and international organizations. It has worked for marginalized and resource poor farmers in the war-torn districts of Apac, Lira, Gulu, and Pader. JAF was initiated with the goal of improving food security, nutrition and income of the community in war-torn areas.

Approach

JAF on its own has been able to mobilise and sensitize different farmer groups on the multiplication, production and consumption of orange-fleshed sweetpotato. It has sourced and distributed planting materials to people taking into account of the security situations. For example, at the peak of insecurity JAF devised a method of dropping planting materials on strategic locations for farmers to access when sneaking back to their fields. Additionally, through establishing viable linkages (Tanganik *et al.*, 1998) to other organisations, JAF has been able to register early successes of using orange-fleshed sweetpotato as a disaster mitigant in northern Uganda. PRAPACE, CIP and NARO provided technical guidance and funds at different stages of the activities. The funds for purchase of the initial planting materials and

facilitation of training of JAF farmers and extensionists were provided by CIP and PRAPACE. CIP also provided additional funds to purchase a motorised sweetpotato chipper to process sweetpotatoes in the event of surplus production. NARO's sweetpotato program mobilised initial planting material among the commercial planting material multipliers in central Uganda. NARO also conducted trainings for JAF lead farmers and extensionists. At the grassroots JAF linked very well with the administration of respective districts and was able to utilise government extension personnel in some activities. Later on during distribution of the sweetpotato roots to the displaced people, JAF forged more linkages with stakeholders concerned with relief food distribution to people in the camps. Among the key linkages were those made to the district administration, Red Cross-Uganda, UNICEF and World Vision International. These provided transport for the mobilised sweetpotato roots to the people in the camps as well as distributing roots to the affected people.

Multiplication and distribution of sweetpotatoes in the northern Uganda.

JAF's involvement in promoting OFSP started in June 2002 with mobilization and sensitization of farmer groups in Apac on importance of orange-fleshed sweetpotato varieties. This was at time when this region was relatively peaceful. This fed into follow up planning meetings with farmer groups that led into forming farmer groups for multiplication, and eventually land preparation. By the second week of July, the first batch of planting material was delivered from Central Uganda. This was followed subsequently by the second and third batch deliveries. A total of 355 bags with estimated 851400 vine cuttings sufficient to plant 28.4 hectares was delivered (Table 1). Using additional funds from CIP, more 100 bags of vines were also delivered and distributed in Apac and Lira during 2003. All the planting material delivered in 2002 was of the variety SPK004 (Kakamega), while in 2003 it was only the variety Ejumula. SPK 004 is an

Table 1: Sources and estimates of planting material acquired by James Arwata Foundation in Northern Uganda, 2002.

Year	Source	Variety	No. of bags	Estimated No. of cuttings	Estimated area (ha)
2002	Luwero Farmers	SPK 004	305	732,600	24.42
	Kampala farmers	SPK 004	50	118,800	3.96
2003	Luwero Farmers	Ejumula	100	240,000	8.0
Totals			455	1,091,400	36.4

introduced orange-fleshed sweetpotato variety from Kenya (Mwanga *et al.*, 2004) that has proven to be high yielding, with high dry matter content, adaptable, and found acceptable in other parts of Uganda. Ejumula on other hand is a local variety that has been highly accepted across Uganda. It is deeper orange than SPK 004, has stable yields and with high dry matter levels (Mwanga *et al.*, 2004).

The first three batches of planting materials largely of SPK were distributed to three farmer groups, two in Lolo Sub County and one in Inomo Sub County all in Apac district. These groups served the dual purpose of multiplying vines and producing the first crop of sweetpotato that was harvested in December 2002. The batch that was delivered in 2003, was largely Ejumula and was spread to more groups. Apart from Lolo and Inomo in Apac, Ejumula was distributed to two more groups in Aduku and Bala sub counties in Apac district and one group in Lira district.

Scaling up of planting material deployment.

It is important to note that all the starter planting material purchased from central Uganda (Table 1) would not have met farmers' demand even if it were delivered as a single batch. A lot of farmers got interested and opened big fields after being mobilized and sensitized by JAF. This meant that the fields, which were planted using the very first batch of the material served as multiplication fields. As early as mid August vine cuttings were ready for distribution to other farmers within

and outside the initial groups. Table 2 shows the documented planting material that had been distributed to other farmers within and outside the initial target districts by JAF by March 2003. In the event that Apac and Lira districts became insecure during the last quarter of 2003, the distributions targeted the war-affected communities, including the war hot spots areas of Gulu and Pader districts. An estimated total of over 4.5 million vine cuttings covering an estimated total area of 151.5 ha have been distributed in the Northern region through JAF coordinated activities. The major beneficiaries have been Apac and Lira where the organization is largely based; a total of over 2.5 million vine cuttings have been distributed in the two districts. This is probably because the organization is based in the two districts, but probably also that the two districts were at the start of the multiplication and distribution activities were relatively peaceful. The activities were affected later when rebels infiltrated Apac and Lira districts. The second major beneficiary was Soroti district courtesy of the government NAADS program. JAF mobilized up to 640 bags of vines among its farmers and delivered then to Soroti. This consignment was estimated to have contained over 1.5 million cuttings and was estimated to have planted up to 51 hectares of sweetpotato fields. In total JAF farmers got Shs 3,840,000 (equivalent US\$ 1930) from sale of planting material.

Other districts like Pader and Gulu are war-hot spots and this probably accounts for the limited distribution of planting materials. This

shows, however, that there is great interest and demand in such areas, despite the difficulties farming communities are going through.

In general the expanded distribution of orange-fleshed sweetpotato planting material has enabled extensive coverage of the vines in the region more so in Apac and Lira districts. Table 3 shows some of the farmer groups that are known to have benefited from scaled up vine cuttings distribution activities. A minimum of 19 farmer groups has directly received planting material from JAF. However a lot more groups have benefited. For example, the number of NAADS groups in Soroti that finally received the planting material remained

unknown to JAF. But also there is a lot more planting material that has exchanged hands among farmers without getting to JAF's notice.

Orange-fleshed sweetpotato as a relief food in northern Uganda. Apart from acting as multiplication fields, the initial planted fields yielded a lot of sweetpotato roots, leaving a lot of surplus roots with the farmers. Fortunately, this was the same time insecurity in the region was at its peak and many people had been forced to live in protected camps. Displaced people had fled rebel insurgency in the various districts that included Lira itself, Apac and especially Pader district. Pader is

Table 2: Scale-up distribution of planting material in war affected areas of the Northern Uganda 2002/2003.

District	No. of bags	Estimates vine cuttings	Estimated area (ha)
Soroti	640	1,536,000	51.2
Gulu	150	360,000	12.0
Pader	50	120,000	4.0
Apac	620	1,488,000	49.6
Lira	434	1,041,600	34.7
Totals	1894	4,545,600	151.5

Table 3: Some of the farmer groups that have benefitted from the expanded distribution of planting materials received from Jamee Arwata Foundation (2002/ 2003).

District	Sub-county	Groups
Lira	Ogur Dokolo Kwera	Akakan, Agweng, Alyec Youth Amwoma, Iguli, Akolodong Apennyang, Agen farmers
Gulu	Bobo	Patek Youth, Adak Women group
Apac	Acaba Inomo Aduku Chegere Minakulu Bala	Ocolo, Apurubonyo, Acaba Youth tree planting group Ajok 'A', Ajok 'B' Ikweru, Adyeda women group Apoki Women Guild Assoc. Omoladyang, Abongwen Youth Afforestation
Soroti	Gweri	NAADS groupsSOCADIDO groups
Totals		>19 groups

one of the rebel hot spots and is neighbouring Lira district. JAF, in its noble mission of joining hands with policy makers, NGO's, research organizations and the rural poor, to bring hope to the hopeless, using funds provided by PRAPACE, donated an estimated 7 tones of orange-fleshed sweetpotato roots to displaced persons in Lira municipality in Lira district. It is estimated that at least 8021 displaced persons (about 1367 households) were fed by the donated sweetpotato. JAF linked to more other organization for a hand in achieving this noble cause. For example, the Lira district administration provided a vehicle that helped to transport sweetpotato fresh roots from three different sub-counties to the distribution centers. Uganda Red Cross volunteers handled the distribution to the affected people. The distribution exercised was overseen by the district administration, UNICEF. The media also witnessed the distribution of the sweetpotato and later helped to publicize the activities by JAF and indeed the orange-fleshed sweetpotato.

This supplemented the traditional cereals and beans that continued to be given out by World Food Program, and the artificial vitamin A tablets given by UNICEF.

The first distribution created demand from other organizations to extend the supplies to other camps in more affected areas of Gulu. In 2003, JAF in collaboration with World Vision International distributed about thirty tones of fresh roots to displaced peoples camps in Gulu.

Achievements

JAF's activities to disseminate orange-fleshed sweetpotato in the war-torn areas of northern Uganda present a number of achievements to JAF and its partners.

Expanded multiplication of orange-fleshed sweetpotato has increased food availability in households and yielded surpluses that have fed displaced people in the various camps (including disparate babies and women). Since its inception, JAF estimates to have distributed planting materials to over 120

groups (included women and youth groups) to all the war affected districts in Northern Uganda. Some of the groups are displaced people who carried planting material back to their villages as conditions improved. On the food relief side, JAF estimates to have distributed over 60 tones of orange-fleshed sweetpotato that is estimated to have fed over 300,000 affected persons (53,000 households) living in the camps in both Lira and Gulu districts for approximately two days each household (Red Cross Relief staff- personal communication)

Financial benefits have also accrued to farmers' and women's groups through the sales of vines and sweetpotato roots. In a period of about a year, participating farmers earned over US\$ 12,000 from sales of vines alone. These earnings are seen as incentives to farmers to sustain production and wider dissemination of orange fleshed sweetpotato in the north especially as the security situation improves. These farmers have become keener and for the first time in the region vines were maintained through the dry season.

These activities have thus contributed in restoring hope among the people. This is reflected in ambitions of Mr. Albino Ebwol, chairperson of Alidi farmers group, when he was asked by Uganda television of what he expected to gain with the sweetpotatoes. He hoped to buy a car and his fellow farmers would build decent permanent home buildings.

JAF has successfully involved and captured the interest of local opinion leaders into its activities on orange-fleshed sweetpotato. A number of officials from the district local councils have also become growers of OFSP.

JAF as an organization has won recognition and appreciation from the local leadership, which is critical for its future activities. For example a vote of appreciation to JAF was discussed and passed by the district council. The council is the local legislating and planning unit at the district. The appreciation recognized the uniqueness of the donated sweetpotato varieties that are

rich in vitamin A and would therefore fight malnutrition in addition to food security.

Lastly promotion of orange fleshed sweetpotato has presented JAF with valuable knowledge and experience in dealing with desperate people that live under continuous uncertainty.

Challenges

Future strategy. It is hoped that the security situation in some parts of the region will improve while other parts remain insecure. JAF will continue to work with farmers in the camps in areas whose security situation is envisaged to improve by availing clean planting material and establish multiplication gardens for the vines. These will be sources of more vines as people settle back into their homes. The multiplication will also be done with people in camps in areas still prone to insecurity to encourage them produce supplementary food using areas within the surroundings of the camps. This will also serve to conserve the vines for these affected families hoping for improvement in the security situations in their areas. Farmers in all the cases will be trained on good cultural practices of producing sweetpotatoes as well as post harvest handling aspects in events of over production. JAF also hopes to continue working with its partners to provide sweetpotato to displaced persons by buying of the surplus from the farmers in secure areas. It will also seek to widen the partnership to more organizations with the aim of getting further support to widen impact to reach all the affected people in the North.

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Appreciation is extended to CIP, PRAPACE and NARO for funds, planting material and knowledge to JAF. Local government personnel for the moral support and keen interest in JAF activities. Other partners like Red Cross, World Vision and UNICEF for distributing sweetpotatoes to people in need.

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Minimal processing of yam to increase consumers' acceptance

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Abstract. Studies were carried out on the minimal processing of yam, a value staple crop among the Ghanaian populace. Yam, reduced to different sizes was minimally processed using two methods (steaming and parboiling). These samples were stored at –20°C over a period of 12 weeks. Sensory evaluation involving 2 sets of panel to assess Product-based and Consumer-based influences was conducted on the stored samples every fortnight to evaluate the colour, texture, taste and size of the yam sample after frying and boiling. Product-based testing for parboiled *pona* shows that taste and colour for the large size yam was the most preferred and it was stable throughout the analysis. The large type also shows that preference increased with storage especially for size and texture. For the steamed pretreated, preference decreased with storage for small type samples while for chips

all the four sensory parameters were acceptable to the consumers. There were varying preferences in some of the sensory parameters for small and medium types. The result of the parboil samples for the consumer-based analysis indicated that with exception of taste all the other sensory parameters were acceptable for both small and large sizes while for medium size and chips preference was for size, and texture. For the steamed samples panelists showed preference for all the sensory parameters for chips while for small size preference decreased with storage. There was a general acceptance for steamed treated chips in both product and consumer based testing. With exception of taste in the consumer-based testing all the other sensory parameters in both testing were well accepted.

Towards the control of a severe form of cassava mosaic disease in Nigeria: diagnostic survey for cassava mosaic begomoviruses

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Abstract. A diagnostic survey was conducted in the southern states of Nigeria to determine if the Ugandan strain of *East African cassava mosaic virus* (EACMV-UG2) has spread to Nigeria. Farmers' fields (290) were visited in which 946 cassava leaf samples were collected in addition to 220 samples of whitefly vectors. The overall impression of cassava mosaic disease (CMD) symptom severity was recorded as mild, moderately severe or severe. Polymerase chain reaction (PCR) tests were conducted on the samples using nucleotide primers for the detection of *African cassava mosaic virus* (ACMV), *East African cassava mosaic virus* (EACMV) and EACMV-UG2. CMD symptoms in most farms in Abia, Cross River, Ebonyi, Ekiti and Imo States were either moderately severe or severe. About the same number of farms had moderately severe and severe symptoms in Ogun, Ondo, Osun and Oyo States. CMD symptoms were mild in most farms in Akwa Ibom, Anambra, Delta, Edo, Enugu and River States. ACMV is the dominant species, occurring singly in 62.2% of samples while EACMV alone was detected in 1.1%. Mixed infections by the two viruses occurred in 22.4% of samples and the remaining 14.3% tested negative to the primers. The two viruses were also detected in the whitefly

vectors. Most of the plants doubly infected with ACMV and EACMV were characterised by severe symptoms. A higher proportion (49%) of farms with mixed infections were observed in the survey area compared to the 14.3% recorded in a previous survey conducted in 1998. Biological variants of ACMV were observed of which some induced very severe symptoms. EACMV-UG2 specific primers tested negative to all the samples. Although EACMV-UG2 may not occur in the area surveyed, virulent strains of ACMV and EACMV seemed to occur. The extremely severe symptoms induced by some isolates of ACMV and by the two viruses in mixed infections underscore the need to make available to farmers, desirable resistant cassava genotypes to sustain cassava production in Nigeria.

Opening Remarks

Honourable Professor Pius P. Mbawala (MP),
Deputy Minister of Agriculture and Food Security

Your Excellency, Dr. Ali Mohamed Shein;
Vice President, United Republic of Tanzania
Mr. Chairman, Hon. Mussa Arne Silima
(MP); Minister of Agriculture, Natural
Resources, Environment and Cooperatives,
Zanzibar
Mr. Mohamed Babu; Regional
Commissioner, Arusha
Dr. Poulter; President of the International
Society for Tropical Root Crops (ISTRC)
Dr. Peter Hartman; Director General,
International Institute of Tropical
Agriculture (IITA)
Distinguished Scientists
Agro- Industrialists
Symposium Participants
Ladies and Gentlemen

1. On behalf of the Ministry of Agriculture and Food Security (MAFS) and on my own behalf I feel greatly honoured to be here with you at the opening of the 13th Triennial Symposium of the International Society for Tropical Root Crops, May I, also commend members of the local organizing committee for successfully staging this Symposium here in Arusha.
2. The theme of the Symposium is on “Tropical Root and Tuber Crops: Opportunity for poverty alleviation and sustainable livelihoods in Developing Countries”. We in Tanzania recognize the importance of these crops. For instance, cassava is the leading root crop in the country ahead of sweetpotatoes, Irish potatoes, cocoyam and common yams. Currently, Tanzania is the fourth largest producer of cassava in Africa. However,

productivity of cassava in the past ten years (1991- 2001) has stagnated at between 8-10 tones per hectare which is equivalent to 2.0 to 2.5 tones of dried cassava per hectare. This yield is slightly below the continent’s average of 10 tones per hectare and much lower than the average yield of 14 tones per hectare obtained in Nigeria, the leading producer of cassava in the world. Potential fresh yields in Tanzania can reach 25 to 30 tons per hectare without inputs.

3. Mr. Chairman, root and tuber crops play a significant role in enhancing food security and providing cash income to many Tanzanians. According to a Dar es Salaam market survey conducted in June 2003 by the Tanzania Food and Nutrition Centre (TFNC), the average supply for cassava was 329,875 metric tones and fetched about she 21.7 million/= . The survey also showed that the annual average supply for sweetpotato was 26,726 metric tones and generated about Shs. 267/= million. That survey further showed that about 30% to 40% of cassava and 10% of sweetpotatoes produced is normally retained for domestic consumption.
4. The low yield of cassava in Tanzania, as compared to the existing potential, is attributed to a multitude of factors including:- use of varieties with low yield potential, incidence of diseases and insect pests such as African cassava mosaic virus (ACMV), cassava brown streak disease (CBSD), cassava bacterial blight (CBB), cassava green mite (CGM) and cassava mealybug (CM), poor crop husbandry, lack of secure markets and alternative uses of the crop.

5. Consequently, farmers need to be motivated to improve their management skills and embark on additional investments in order to improve productivity and quality of the produce. The challenge facing scientists and political leaders is therefore, how to develop a system, that will integrate the production of cassava, in the right amount, its transformation into easily storable product(s) that possess desirable quality attributes, and its marketing at prices consumers and other end-users are willing to pay. These are issues that feature high, in the agenda of this week long Symposium for the cooperation and continued support received from the International Centre for Potato Improvement (CIP) in developing control options against priority problems. We thank cassava farmers and scientists working on cassava and tubers.
6. Mr. Chairman, having briefly given these introductory remarks it is now my great pleasure and honour to humbly invite His Excellency Dr. Ali Mohamed Shein, The Vice President of the United Republic of Tanzania, to give his Opening Address and to also officially open this Symposium.

THANK YOU.

Official opening speech

His Excellency Dr. Ali Mohamed Shein
Vice-President of the United Republic of Tanzania

Mr. Chairman, Hon. Mussa Ame Silima (MP); Minister of Agriculture, Natural Resources, Environment and Cooperatives, Zanzibar

Hon. Charles N. Keenja (MP), Minister of Agriculture and Food Security, Mainland Tanzania

Hon. Mohamed Babu; Regional Commissioner, Arusha

Dr. N. Oulter; President of ISTRC

Dr. Peter Hartman; Director General, International Institute of Tropical Agriculture (IITA)

Distinguished Scientists

Dear Participants

Ladies and Gentlemen

It is my great pleasure and privilege to be invited to deliver the Opening Address of the 13th Symposium of the ISTRC. On behalf of the Government and the people of Tanzania, I welcome you all, and in particular our foreign participants to Arusha and Tanzania. May I also use this opportunity to extend my special welcome and thanks to Dr. N. Poulter, President of the International Society for Tropical Root Crops and other members of the Executive Council for honouring our country with the privilege of hosting this very important international scientific meeting. This meeting, I am told, was last held in the African continent in 1991 in Ghana.

The theme of the Symposium:- Tropical Root and Tuber Crops: Opportunities for Poverty Alleviation and Sustainable Livelihoods in Developing countries – is most appropriate and timely to our own situation. In Tanzania, the potential contribution of tropical root and tuber crops to sustainable livelihoods cannot be over-emphasized. For

example, in the year 2002/03 the total contribution of roots and tubers to total food production in the country was 30 per cent.

Mr. Chairman, agriculture in Tanzania is the most important sector in the national economy. The sector contributes about 50% of the Gross Domestic Product (GDP), 56.2% of export earnings and provides employment for over 80% of the working population. The agricultural sector is also the major source of food for the population and for raw materials for industrial sector. Agricultural development in Tanzania is therefore crucial in achieving the objectives of employment, food security, income generation and poverty reduction on which the government has laid great emphasis. According to the 2002 census Tanzania has a population of 34.4 million inhabitants with an annual growth rate of 2.9 per cent. The country also has abundant land resources with a total area of 94.5 million hectares, out of which 44 million hectares of land is classified as suitable for agriculture. Recent studies however indicate that only 10.1 million hectares of the arable land (23 per cent) is under cultivation. It is also estimated that 50 million hectares is suitable for livestock production while only 50 per cent (i.e. 26 million hectares) is used. Nevertheless, Tanzania ranks third in livestock numbers in Africa with an estimated 18 million head of cattle.

Despite this abundance of the land resource, Tanzania's agriculture is predominantly characterized by small-scale subsistence farming occupying an estimated 85 per cent of the arable land currently in use. Also the land under irrigation is currently limited to an estimated 0.2 million hectares while there are 2.3 million hectares of land with very high development potential for irrigation. The reasons for our failure to utilize this vast natural resource is our low investment capacity in the agricultural sector, prevalence

of insect pests and diseased and inadequate rural infrastructure. The Minister has already alluded to these issues in his remarks.

In recent years the performance of agricultural sector has shown a positive trend as mentioned by the Minister. In the year 2003 the production of food crops in the country was 8.5 million tons, out of which 4.1 million tons were cereals and 4.4 million tons non-cereals. Root and Tuber crops particularly cassava, sweetpotato and irish potatoes contributed 50% of the non-cereals food crops component. In the same year, production of major cash crops (coffee, cotton, cashew, sugar, tea and tobacco) was on average 19.8% higher than the previous year.

Processing of both food and cash crops locally is being emphasized in order to add value of the products, to diversity utilization of the agricultural products at household and industrial levels, and to compete well at local and international markets. In 2003, the private sector was sensitized and it is responding well in establishing and improving local processing plants for cash crops such as cashew nut, tea, coffee and cotton. The government is urging the private sector to invest in the processing of food crops including roots and tubers, fruits, livestock products etc.

Mr. Chairman, our vision is to have an agricultural sector that by the year 2025 is modernized, commercial, highly productive and profitable, and that utilizes natural resources in an overall sustainable manner, and acts as an effective basis for intersectoral linkages. In order to support the Agricultural sector the government has put into place several national policies and strategies which include:

1. The Poverty Reduction Strategy Paper (PRSP)
2. The Rural Development Strategy (RDS)

3. The Agricultural Sector Development Strategy (ASDS)
4. The Tanzania Agriculture and Livestock Development Policy (1997) and
5. The Cooperative Development Policy (2002).

The Poverty Reduction Strategy Paper (2000/01) has outlined the growth targets for the agricultural sector for the coming five years as follows:-

1. Increase real annual agricultural GDP growth from 3.6% to 6% by year 2005.
2. Increase annual growth rate of export crops from 6.8% to 9% by the year 2005.
3. Increase real annual growth rate of the livestock component from 2.7% to 5% by year 2005.

Mr. Chairman, in August 2001, the Government of the United Republic of Tanzania approved the country's Agricultural Sector Development Strategy (ASDS) to provide a basis for action by both the public and private sector towards the growth of the agricultural sector. The ASDS, which is one of the major components of the Rural Development Strategy (RDS), stems from the Agricultural and Livestock Policy as well as Cooperative Development Strategy of 1997. All these strategies and policies are in line with the Tanzania Development Vision (TDV) 2025.

Mr. Chairman, may I at this juncture, very briefly talk about the range of reform programmes implemented by the Government of the United Republic of Tanzania. There are reforms taking place in relation to monetary policies, fiscal policies (public expenditure, taxes, subsidies) and trade polities (liberalization of markets, privatization and divestiture of state enterprises). These

reforms have created a commercially oriented macro-economic environment. Input and output markets have been largely liberalized and private traders and farmer organizations are increasingly providing services to farmers. The private sector is expanding rapidly in response to the favourable economic and policy environment. The liberalization of markets, decontrol of foreign exchange markets, and removal of trade restrictions and monopoly marketing has had profound influences on the agricultural sector. The main thrust of the national policy framework is to transform the Tanzanian economy and make it more commercialized and marketing-oriented. The ASDS and its implementing programme i.e., Agricultural Sector Development Programme (ASDP), place greater emphasis on stakeholder-led agricultural development.

Mr. Chairman, one of the critical issues necessary for the development of the agricultural sector as identified in the Agricultural Sector Development Strategy, is the clarity of the public and private roles in improving support services, including agricultural research, extension and training. The private sector is expected to increase its role in providing a wide range of demand driven support services to smallholder farmers. The public sector, on the other hand, will gradually, but increasingly, limit its role to financing the provision of collective goods and services that the private sector is unwilling or unable to provide, and the targeted financing of goods and services to eventually overcome rural poverty and create rural wealth.

However, the progress so far has been made by the sector in crop marketing that has been largely liberalized and private traders and farmer organizations are increasingly providing services to farmers. The private sector is expanding rapidly in response to the favourable economic and policy environment.

Mr. Chairman, we believe that these policy reforms, together with good governance and enhanced people's participation in decision making will accelerate the growth of the

agricultural sector and contribute significantly to poverty alleviation.

Mr. Chairman, to go back to the theme of this Symposium; in most of our developing countries particularly in Sub-Saharan Africa, root and tuber crops are closely associated with food security and complement the objectives of protecting mankind against malnutrition. They also have potential in providing opportunities of revenue generating activities for most rural dwellers and provide the bulk of the daily caloric intake of majority of our people.

On the other hand, the potential use of root and tuber crops as a source of cheap feed for the development of the livestock industry and as a source of starch for chemical and confectionery industries has to a large extent not been fully explored in these countries. The Government of the United Republic of Tanzania having recognized the enormous contribution which roots and tuber crops could make to the attainment of the objective of the Poverty Reduction Strategy Paper (PRSP), has decided to actively promote efficiency in the production, processing, marketing and utilization of these crops to their full potential.

Mr. Chairman, the theme of the symposium: Tropical Root and Tubers Crops; Opportunities for Poverty Alleviation and Sustainable Livelihoods in Developing Countries, is a theme that is raising hopes and aspiration's of millions of small scale farmers engaged in the production of root crops many of whom are at subsistence level. I, too, share their hopes that your deliberation this week will provide the solutions/ technologies that will transform the lives of these farmers and improve their well-being.

It is to my expectations therefore that at the end of your deliberations in this important symposium you will provide some insight into the following areas:-

1. Identification of technologies and strategies that will transform the tropical root crops from their rural subsistence

status to cash crops for both manufacturing and food processing industries.

2. Technologies that will reduce production bottlenecks and increase productivity to reach the biological potentials of these crops while conserving the environment in the countryside where these crops are grown.
3. Devise ways and means to enhance increased technical cooperation between National Agricultural Research Systems (NARS), International Research Institutes and other stakeholders.

Mr. Chairman, I need not remind the eminent scientists gathered here today that “Information is power”. However I need to remind them that they are working for small-scale farmers who have no access to information. Therefore it is also my expectation that the deliberations and recommendations from your Symposium this

week will reach these farmers and all stakeholders in good time and in a user-friendly manner.

Before I conclude, I wish to remind our foreign friends not to spend all your five days in Tanzania within the walls of the Conference Hall. Kindly, try and organize your schedule so as to have a few hours for play and site seeing particularly some of the tourist attractions located a few hours drive from here.

On behalf of the Government of the United Republic of Tanzania, may I take this opportunity once again to express my gratitude and appreciation to International Society for Tropical Root Crops for organizing this symposium in Tanzania, East Africa. We welcome you to stage another meeting here any time you wish – KARIBUNI SANA.

Your excellencies, distinguished scientists, Ladies and Gentlemen, on this note I now have the pleasure and honour to declare the 13th symposium of the International Society for Tropical Root Crops officially opened.

THANK YOU

Production of amylose-free sweetpotato plants by RNAi

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Abstract. In sweetpotato roots (*Ipomoea batatas* (L.) Lam., cv. Kokei 14) 18 to 20 % of the starch is amylose and the other major component is amylopectin. Granule-bound starch synthase I (GBSSI) is one of the key enzymes which catalyzes the formation of amylose in starch granules, a linear α -(1,4)Dglucan polymer, from ADP-glucose. In this study, sweetpotato plants were transformed to produce amylose-free starch by RNA interference (RNAi). The gene construct that encoded double stranded RNA (dsRNA) of *GBSSI* first exon was introduced into the sweetpotato genome by *Agrobacterium tumefaciens*-mediated transformation to inactivate the endogenous *GBSSI* gene. Starches from 80% of transgenic lines showed red-brown staining pattern by iodine staining, indicating a reduction of amylose content. Starches from these transgenic plants, which showed red-brown staining pattern were confirmed to be amylose-free by calculations from the blue value at 680 nm.

Yam production in Ghana: To stake or not to stake - A plant breeding perspective

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Abstract. Staking is the yam planter's main concern especially in the yam growing areas of Forest-Guinea Savannah Transition and Coastal Savannah of Ghana. Staking is not only laborious, but also very costly. The environmental degradation due to deforestation is also enormous. Various agronomic approaches such as the use of plastic mulch, varying length of stakes among others, have been recommended in the past to solve this problem. This paper presents a breeding perspective for solving the yam staking problem by assessing white yam (*D. rotundata*) and water yam (*D. alata*) genotypes under staking and non-staking conditions and discussing the environmental impact of staking.

The status of sweetpotato improvement and promotion in Nigeria

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Abstract. Although sweetpotato has great potential, it has not been promoted in Nigeria. IITA and some regional research centres have carried out limited research on sweetpotato by IITA and regional research centres, although documentation of results has been poor. The potential of sweetpotato lies in its capacity to grow well in areas with less rainfall and soil fertility compared to other crops. A huge opportunity for sweetpotato promotion in Nigeria is the potential role it can play in the rural household food security given that up to 74% of Nigerians live in rural areas. In addition, the crop can be made into other products, thus diversifying its utility base and therefore assuring its market. Sweetpotato production promotion in Nigeria will have to consider introducing a wide range of varieties for adaptability and acceptability tests, while planning for a sustainable seed multiplication and distribution system.

Neglect of a good crop. Use of sweetpotato in Nigeria dates back to the period 1594-1698 when Portuguese traders introduced it. In the last 300 years, little has been done to promote the crop in areas where it has comparative advantage. This is mainly because there are other alternative food crops. Any organized promotion of the crop will yield more benefits to Nigeria. It will adequately supplement the food and cash supplies to farming households in the area. In 1999, the grain stock in reserve was 200,000 tonnes for a country of over 100 million heads (Abdullahi, 1999). Thus, at 20%

dry matter, this will be equivalent to 800,000 tonnes of sweetpotato roots that can be obtained from just 123,000 ha of land given the present yield levels of 6.5t/ha. This drive that can be achieved given some support.

The crop is well patronized as a daytime snack in schools and offices. It is consumed boiled, or sold as fried chips or crisps in polyethylene satchets.

Crop variety is the main variable in the system that farmers often manipulate to raise yields. For this reason, sweetpotato varieties that are higher yielding than the many local clones need to be identified and released after a good multiplication programme. Until some effort is put in this regard, sweetpotato will continue to be produced using low yielding varieties.

Sweetpotato research: IITA, Ibadan. Every effort must be made to document into one volume all the results of research done by IITA (during 1971-1988) for use by upcoming researchers and developers in Nigeria and the African sub-region. Such a publication will be a good promotion of the crop. Otherwise many who need local information on the performance of the crop in Nigerian environments will not have them. It will continue to be considered a small secondary despite its well-known potential.

Sweetpotato research: NRCRI, Umudike. Annual reports on research and development work on the crop from the NRCRI are scarce.

of the total cultivated area was under sweetpotato.

Nigeria-Chad-Niger Sweetpotato Trade. There is long standing trade between Nigerian farmers in the project area and the northern neighbour nations. This trade can be studied and organized to the benefit of all concerned stakeholders. Nigeria will be the producer and supplier whereas those countries will remain buyers. As this sweetpotato commodity chain has not been organized or even understood in a technical or economic way, it remains inefficient and the farmers are yet to reap the full benefits of the crop in this situation.

Benefits from sweetpotato enterprise. Nowhere can the benefit of a crop enterprise be more evident than through an examination of the crop budget. The crop can give a cash return in 3.5-4.5 months.

Use of sweetpotato in poultry and pig farming is very well established. Tewe (1998) reports attempts to pelletize sweetpotato flour along with the vines and leaves as a complete feed for rabbits and other livestock. Tewe *et al.* (2001) however suggested that the price of sweetpotato should be around N3.0/kg to be competitive with cassava that sells for around that price. In Delta state, the 2000 season net revenue of N2951.23 was realized from a net investment of N7935.5, which gave a 37.19% return to investment when sweetpotato roots sold for N25/kg (\$0.20) (Iken *et al.*, 2000).

Nigeria's industrial economy is warming up to the production of alcohol from starchy crops. Sweetpotato has a good potential for alcohol production. Ethanol yields from sweetpotato vary with variety (0.07-0.15 litre/kg fresh root); and was significantly correlated ($r=0.96^{**}$) with root dry matter percentage among the nine varieties studied (Collins, 1984).

Sweetpotato hectareage and yields. In Delta State in southern Nigeria, sweetpotato yields were 8.28-11.33 t/ha when intercropped with

If that situation continues, it will be difficult for *promoters* of the crop to justifiably have basis for recommending practices arising from NRCRI's work or even to ask would-be investors to go to NRCRI for more information. The need for research results and other information on the crop to be in the public domain is self-evident.

Weather and sweetpotato cultivation in northern Nigeria. Sweetpotato matures in 4-5 months and thrives well in areas with 750-1000 mm of annual rainfall. In those few months, it produces far more *reliable dry food* than maize, sorghum, cassava, and millet kilogram per hectare. Sweetpotato gives a good yield when harvested three months after it is planted. The yield is higher at four months after planting and even more so at full maturity at five months. The advantage is that there is always a yield or roots to harvest. There are different kinds of varieties that can assure a good yield of roots and forage to the great majority of poor farmers who cannot pay for the *higher costs of inputs* needed to grow these other crops. Thus, any intervention to help the teeming majority of Nigerians will require a *shift from the usual crops* to one that is within the capability of the farmers.

Sweetpotato in the Rural Economy. Only 36.3% of Nigerians live in urban areas (NPC, 1998). Thus, the majority of the populace is rural. The needs of these rural dwellers should form the focus in any development project. Consequently, farming should be targeted to the least cost option for the poor who have very little income or security for themselves and their families.

Bauchi State is a major food producing state in north-eastern Nigeria having borders with seven other states. Its agriculture captures the pattern in that zone of the country. Bauchi State has 3,675,000 cultivable hectares but only 975,371 ha were cultivated in 2000 (i.e. 26.5%). The sweetpotato crop is not emphasized. It is ranked 9th out of the 20 principal food crops in the state. About 4.3%

pepper (Iken *et al.*, 2000). The Agricultural Development Programmes (ADPs) of the 36 states and the Federal Capital territory conduct Crop and Yield Surveys (CAYS). There is need to collect and assemble information on the crop to allow researchers and developers to better understand the commodity chain with a view to proper planning of strategies. Sweetpotato information is tucked under the term “other crops” or “root and tubers”. In that way we do not fully grasp the role it plays.

From the available figures for the FCT, about 619 ha are cultivated in the rainfed and fadama crop of sweetpotato each year. This is significant considering that the area is mainly urban. For Kaduna State, the change in sweetpotato yields (between 1994 and 1995) suggests a change from subsistence to a commercial farming practice due to increased demand from the influx of population to the FCT. Whether these yield data pertain to sole plots as in commercial production or to sweetpotato in mixed cropping of varied stand intensity as in subsistence food production is not clear. Chinaka (1983) puts root yields as 4.0 t/ha under farmer local practices. Tewe *et al.* (2001) reported yields of 3-7 t/ha for various enclaves of sweetpotato production across Nigeria. Based on the foregoing data, one could assume 6.5 t/ha as fair average.

In Ogun State in 2001, about 4% of the farmers grew an average of 0.10ha to sweetpotato (Vaughan and Adeogun, 2002). In Ikorodu Local Government Area of Lagos State, the average non-tractorised farm holding was 0.8ha for a range of 0.2-1.0ha compared to 2.0ha with a range of 0.2-6.0ha for tractorised farms (Aromolaran *et al.*, 2002).

In Kaduna State, small farmers that predominate (70% of the farming population) cultivate 0.5-2.5 ha per farming household. 1998, their sweetpotato crop of about 280,000 ha was second only to maize in hectares cultivated. Statistics of sweetpotato production in Nigeria is not clearly known, although an estimate of 355,000 ha is reasonable. This is for 16 of the 36 states and FCT or about 43.2% of the country. Thus, if all produce sweetpotato at 3.5% of their farm

area, Nigeria's annual sweetpotato area would be around 821,000 ha.

Sweetpotato in seed programmes. No ADP undertakes any programme for multiplication and distribution of sweetpotato planting materials. This bias is not deliberate. No case of the great potentials of the crop has been demonstrated. Losses of the crop are too high and the absence of a strong postharvest component has hindered the acceptance of the crop as a *co-contender* with other root crops.

Sweetpotato and poverty alleviation campaigns. “Sweetpotato is a good alternative to yam [in parts of Delta state of Nigeria]. It is a hardy crop that thrives in soils that cannot sustain yam production. Many farmers embrace the cultivation of the crop because of the reduced tedium involved in its cultivation as compared to yam. Although the crop is cultivated sole, many farmers are looking for appropriate crops for gainful intercropping” (Iken *et al.*, 2000). Again, Ikeorgu (2000) has stated that: “As a food security crop for rural poor households, government in view of its poverty alleviation programme should encourage this crop. The future of sweetpotato appears brighter than the other root crops...” We also believe that if the food production data available were properly analyzed (Aiyedun, 1999), then the conclusion of Ikeorgu (2000) would be upheld.

Storage of sweetpotato and preservative processing. Nwana (1978) reported *Cylas* spp. leaf damage of 11-40 holes per 20 leaves and root damage of 8-13 holes per 25 m² plots for eight sweetpotato varieties. In these plots, yields reached 45-64 kg per 25 m² plots equivalent to 18-25 t/ha after 120 days of growth. To avoid the great loss of root materials, early processing into storable food is highly recommended.

The store of food available to poor farm households can be augmented without the usual losses associated with the storage of fresh roots if such roots are processed into

spari (sweetpotato granules made using the same procedure for making *gari* from cassava roots) immediately after harvested. In the form of *spari*, sweetpotato can be stored for over a year without change in its food value. Sweetpotato flour or chips are also dry products that can be easily stored compared to fresh tuberous roots. The shift from fresh items to *dry storable* items of food is a major challenge for poor households.

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Time of harvesting and its effect on the quality of flour from four cassava varieties

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Abstract. Four varieties of cassava (*Afisiafi*, *Tek bankye*, *Abasafitaa* and *Gblemoduade*) were harvested each month from 9 to 15 months after planting and processed into flour. The yield of flour and some of its physicochemical properties were studied to determine how they were affected by harvesting time and varietal difference. The properties of flour studied were: moisture, ash, crude protein, crude fibre, pH, swelling power, solubility, starch yield, amylose content and pasting characteristics. *Afisiafi* and *Tek bankye* both had their peak flour yields (23% and 22.4% respectively) at 13 months after planting while *Abasafitaa* and *Gblemoduade* had their peak flour yields (23.4% and 20% respectively) at 12 months after planting. Both *Afisiafi* and *Tek bankye* had flour yields increasing uniformly from 11 to 13 months after planting after which they fell while *Abasafitaa* and *Gblemoduade* had their flour yields increasing from 9 through 12 months after planting after which they fell. Moisture content ranged between 6.3% and 14.6%, while ash content was between 0.70% and 2.21%. All flour samples had pH ranging between 5.07 and 6.65 indicating unfermented flour of high quality. All the varieties had a minimum crude protein content of 0.22%; *Afisiafi* and *Tek bankye* had maximum values of 1.53% and 1.68% respectively at 9 months after planting while *Abasafitaa* and *Gblemoduade* had maximum values of 1.68% and 1.53% respectively at 15 months after planting. Starch yield was between 53.60% and 76.01% while solubility ranged between 7.81% and 18.80%. Age significantly affected

($p < 0.05$) flour yield, crude protein, ash and moisture, while pH, crude fibre, amylose and swelling power were neither affected significantly ($p > 0.05$) by age nor variety. Starch yield of flour, solubility, ash content and pasting characteristics were all significantly affected ($p < 0.05$) by variety. *Afisiafi* and *Tek bankye* had higher peak viscosities than *Abasafitaa* and *Gblemoduade*. Both hot paste stability and hot paste breakdown were highest for *Gblemoduade* and lowest for *Abasafitaa*. *Afisiafi* and *Tek bankye* had higher retrogradation while that of *Abasafitaa* and *Gblemoduade* were close to zero.

Introduction

Cassava is one of the most important root crops in the world providing energy to consumers due to the large amount of carbohydrates in its roots. It contributes significantly to the economy of most tropical countries through its processing into various products. In Ghana, its multiplication in the formal planting material sector started in the nineties, with the release of four new varieties; *Afisiafi*, *Tek bankye*, *Abasafitaa* and *Gblemoduade*. These varieties are high yielders, disease and pest resistant when compared to existing local varieties (RTIP Factsheet, 2002). Apart from *Tek bankye*, the other three varieties are not mealy, thus, their acceptability by farmers is low. In Ghana, cassava is mostly pounded into *fufu*, a thick paste prepared by pounding peeled, boiled cassava roots, and eaten with soup *fufu*

requires mealy cassava. It has therefore become necessary to find alternative uses for these high yielding and disease resistant cassava varieties. They may be processed among others into, high quality flour and starch for industrial use. Little, however, is known about their physicochemical properties of flour in relation to age at harvest.

The objective of this study, therefore, was to determine the effects that age and varietal difference had on the yield and physicochemical properties of flour obtained from these four varieties.

Materials and Methods

Source of raw materials. Cassava varieties were obtained from experimental plots at the Wenchi Agricultural Research Station (WARS). The four varieties studied are *Afisiafi* (AF), *Tek bankye* (TEK), *Abasafitaa* (AB) and *Gblemoduade* (GB). The varieties were harvested at 9, 10, 11, 12, 13, 14 and 15 months after planting and processed into flour.

Processing of cassava tubers into flour. Fresh tubers were peeled a day after harvesting and washed. They were grated finely, and the mash packed into porous woven polyethylene sacks and dehydrated manually by pressing with a screw-press. The cakes obtained from pressing were stored in a freezer to prevent fermentation. The frozen cakes were thawed and pulverized the following day, sieved and spread thinly on raised wooden platforms lined with black polyethylene film, and allowed to dry in the sun with intermittently stirring. The dry granules obtained after 2 days of sun drying were milled and sieved through a 60µm mesh. The resulting fine flour was packaged in transparent polyethylene bags and stored at room temperature. The yield of flour was determined by weighing the amount obtained from processing 100kg of fresh tubers.

Physicochemical analyses. Moisture, ash, crude fibre and crude protein contents of the

flour were determined by the AOAC (1990) method. pH was determined by mixing 10 g of flour with 25 ml distilled water, stirring thoroughly and measured with a pH meter (HANNA Instruments, model 8521) at room temperature. Starch yield of flour was determined by preparing a slurry with 10 g of the flour in water and repeatedly washing out the starch with water. The starch was allowed to settle and decanted after which it was dried in a hot-air oven at 50°C overnight and weighed. It was then expressed as a percent of the flour weight. Amylose content, swelling power and solubility of the flour were determined by the method of Barimah (1999). Pasting characteristics was also determined by using the Brabender Amylograph (700cmg cartridge, 6% flour suspension).

Statistical analysis. Two way analysis of variance without replication was used to determine the effects that harvesting time or age and variety had on the selected physicochemical properties. Least significant difference (LSD) was used for mean separation.

Results and Discussion

Flour yield. Flour yield was between 8-23% for *Afisiafi*, 10.6-22.4% for *Tek bankye*, 13-23.4% for *Abasafitaa* and 9.4-20% for *Gblemoduade* (Table 1). Flour yield of *Afisiafi* fell from 9 months through 11 months after planting (March to June), after which it rose uniformly reaching a peak at 13 months after planting, from where it fell again through 15 months after planting. *Tek bankye* had its flour yield falling from 9 months to 10 months after planting, after which it rose uniformly until 13 months after planting; it then fell uniformly until it reached 15 months after planting. *Abasafitaa* and *Gblemoduade* had a similar trend for flour yield. They both rose sequentially from a minimum yield at 9 months old until they reached a peak at 12 months after planting, after which their yields fell uniformly until 15 months after planting. All the cassava varieties had low flour yield in

April. This is because the rains started in late March, and by April the plants had mobilized most of the starch stored in their tubers for germination or new shoots formation (Githunguri *et al.*, 1998). This clearly shows that apart from the age of plant at harvest, the month in which harvesting of the tubers occurred also affects yield of the flour. *Afisiayi* and *Tek bankye* had optimum flour yields at 13 months after planting while *Abasafitaa* and *Gblemoduade* had optimum yields at 12 months after planting. Flour yield was significantly affected ($p < 0.05$) by both age and variety.

Moisture. Moisture content of the flour samples ranged between 6.34-14.58% (Table 2). Flour samples were sun dried from March to December, when rainfall and sunshine patterns were unpredictable and non-uniform. It is worth noting that moisture content of

flour is influenced by the extent of drying and the rainfall pattern during the period of sun drying. Statistical analysis revealed that age significantly affected ($p < 0.05$) the moisture content of the flour samples.

Ash. Ash content of *Afisiayi* ranged between 0.80-1.47%, respectively, while *Tek bankye* had values between 0.70-1.26% with the lowest value at 9 months and the highest at 10 months after planting. *Abasafitaa* had ash content between 0.87-2.21%, representing 15 months and 12 months after planting respectively, while *Gblemoduade* had ash values in the range of 0.88-1.94% with the lowest value at 14 months and the highest at 12 months after planting.

With the exception of *Tek bankye* which had its highest value at 10 months after planting, all the other varieties had peak ash content at 12 months after planting (Table 3).

Table 1: Yield of flour from four cassava varieties at different ages.

Flour yield	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	13.8	14.4	13.0	9.4
10 months	14.4	10.6	15.5	12.6
11 months	8.0	14.8	16.4	16.2
12 months	14.2	21.0	23.4	20.0
13 months	23.0	22.4	20.0	14.0
14 months	14.0	21.0	15.0	13.6
15 months	12.6	19.4	13.6	10.0

LSD for age =3.77; LSD for variety =2.85.

Table 2: Moisture content of flour from four cassava varieties at different ages.

Moisture	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	9.90 (0.01)	9.53 (0.03)	12.10 (0.01)	10.64 (0.02)
10 months	8.89 (0.02)	12.47 (0.11)	10.84 (0.00)	10.64 (0.01)
11 months	11.26 (0.02)	13.20 (0.01)	12.37 (0.01)	14.58 (0.00)
12 months	11.47 (0.01)	13.18 (0.00)	11.00 (0.04)	11.52 (0.01)
13 months	10.96 (0.00)	10.15 (0.01)	6.68 (0.01)	6.34 (0.01)
14 months	11.14 (0.01)	7.24 (0.01)	7.80 (0.02)	12.23 (0.00)
15 months	11.37	11.75 (0.00)	11.34 (0.00)	11.29 (0.00)

LSD for age =2.07.

The ash content of *Tek bankye* fell sequentially from 10 months after planting until 15 months after planting. There was an inconsistent trend in ash content for the other three varieties. Age significantly affected ($p<0.05$) ash content of the cassava flour samples.

pH. pH is an important parameter in determining the quality of cassava flour since pH of 4 or less indicates appreciable level of fermentation, and hence some starch breakdown. Such fermentation also imparts undesirable flavour to the cassava flour making it less preferred when used in baking. The flour samples had pH between 5.07 and 6.65 (Table 4), indicating that they were of good quality. pH was neither significantly affected ($p>0.05$) by age nor by variety.

Crude protein. Crude protein content of *Afisiafi* ranged between 0.22% and 1.53%. The

lowest and highest values occurring at 12 and 9 months after planting, respectively. *Tek bankye* had crude protein values between 0.22-1.68% with the lower limit at 11 months and the upper limit at 9 months after planting. For *Abasafitaa* the range was 0.22% - 1.68% with the lowest value at 13 months and the highest at 15 months after planting. The protein content range for *Gblemoduade* was 0.22% - 1.53% with the lowest value at 12 and 13 months after planting and the highest at 15 months after planting.

Age significantly affected ($p<0.05$) crude protein content. Other factors such as nitrogen content of the soil and the differing rates of nitrogen metabolism in the growing plants may be responsible for the differing trends in crude protein content (Table 5) among the four varieties. It is important to note that both *Afisiafi* and *Tek bankye* had maximum crude protein content at 9 months after planting while *Abasafitaa* and

Table 3: Ash content of flour from four cassava varieties at different ages.

Ash	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	0.80 (0.00)	0.70 (0.00)	1.36 (0.00)	1.21 (0.00)
10 months	1.21 (0.00)	1.26 (0.00)	1.00 (0.00)	1.31 (0.00)
11 months	1.15 (0.00)	1.12 (0.00)	1.17 (0.00)	0.95 (0.00)
12 months	1.47 (0.00)	1.06 (0.00)	2.21 (0.00)	1.94 (0.01)
13 months	1.23 (0.00)	0.83 (0.00)	1.15 (0.00)	0.99 (0.00)
14 months	0.82 (0.00)	0.83 (0.00)	1.24 (0.00)	0.88 (0.00)
15 months	0.82	0.79 (0.00)	0.87 (0.00)	0.99 (0.00)

LSD for age =0.28.

Table 4: pH of flour from four cassava varieties at different ages.

pH	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	5.86 (0.01)	5.46 (0.00)	5.53 (0.00)	5.47 (0.00)
10 months	5.49 (0.01)	5.13 (0.01)	6.21 (0.00)	6.61 (0.01)
11 months	5.63 (0.00)	6.51 (0.01)	5.27 (0.00)	5.30 (0.00)
12 months	6.40 (0.01)	5.31 (0.01)	6.15 (0.00)	6.54 (0.00)
13 months	5.07 (0.00)	6.65 (0.00)	5.67 (0.00)	5.97 (0.01)
14 months	6.27 (0.02)	6.02 (0.01)	5.32 (0.00)	5.55 (0.01)
15 months	5.28	5.11 (0.00)	5.49 (0.00)	5.31 (0.00)

Gblemoduade had maximum crude protein at 15 months after planting. All varieties had a minimum value of 0.22%.

Crude fibre. *Afisiafi* had crude fibre content of between 0.77-2.62%, with the lower limit at 14 months and the upper limit at 11 months; *Tek bankye* had values in the range of 1.45-2.07% with the lower and the upper limits at 9 and 10 months respectively. *Abasafitaa* on the other hand, had crude fibre values between 1.27-2.11% with the lowest value at 12 months and the highest at 9 months, while *Gblemoduade* had its fibre content in the range of 1.62-2.56% with the lower and upper limits at 13 and 9 months respectively (Table 6). There was no significant difference ($p>0.05$) in crude fibre content between ages and varieties. This may be due to the fine sieving of the flour after milling that removed most of the fibre and therefore shielded the effects of age and variety on the fibre content.

Starch yield. Starch yield of *Afisiafi* was between 53.6-75.5% with the lowest value at 9 months and the highest at 10 months, *Tek bankye* had starch yield values between 67.3-73.8%, with the lower limit at 10 months and the upper limit at 13 months. *Abasafitaa* starch yield ranged from 64.1-75.7% with the lowest value at 11 months and the highest at 14 months, while *Gblemoduade* had values between 63.8-76.0% with the lower and upper limits respectively at 14 and 13 months after planting. Surprisingly, starch yield was neither significantly affected ($p>0.05$) by age nor by variety (Table 7).

Amylose. Amylose content of *Afisiafi* ranged between 16.5-34.6% with the lower and upper limits respectively at 9 and 12 months, while *Tek bankye* had values between 20.3-36.0% with the lowest value at 14 months and the highest at 10 months. *Abasafitaa* had amylose content of 20.8-36.0% with the lower and upper

Table 5: Crude protein of flour from four cassava varieties at different ages.

Crude Protein	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	1.53 (0.00)	1.68 (0.06)	0.51 (0.06)	0.66 (0.00)
10 months	0.80 (0.06)	0.66 (0.00)	0.66 (0.00)	0.36 (0.06)
11 months	0.66 (0.00)	0.22 (0.00)	0.66 (0.00)	0.66 (0.00)
12 months	0.22 (0.00)	0.66 (0.00)	0.66 (0.00)	0.22 (0.00)
13 months	0.36 (0.06)	0.66 (0.00)	0.22 (0.00)	0.22 (0.00)
14 months	1.09 (0.00)	0.66 (0.00)	1.09 (0.00)	1.24 (0.06)
15 months	1.52	0.95 (0.06)	1.68 (0.06)	1.53 (0.00)

LSD for age =0.41.

Table 6: Crude fibre of flour from four cassava varieties at different ages.

Crude Fibre	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	1.90 (0.00)	1.45 (0.00)	2.11 (0.00)	2.56 (0.00)
10 months	2.22 (0.00)	2.07 (0.00)	1.84 (0.00)	2.54 (0.00)
11 months	2.62 (0.00)	1.57 (0.00)	1.92 (0.00)	1.82 (0.00)
12 months	2.52 (0.00)	1.67 (0.00)	1.27 (0.00)	1.69 (0.00)
13 months	1.89 (0.00)	1.52 (0.00)	1.69 (0.00)	1.62 (0.00)
14 months	0.77 (0.01)	1.46 (0.00)	1.47 (0.00)	1.78 (0.00)
15 months	1.98	1.58 (0.00)	1.76 (0.00)	1.99 (0.00)

limits at 14 months and 9 months respectively, while *Gblemoduade* also had values in the range of 23.1-34.6% with the lowest and highest values at 13 and 15 months, respectively. *Afisiafi* amylose values rose sequentially from 9 months after planting to a peak at 12 months after planting after which it fell sequentially until 14 months after planting. The other varieties showed no consistent trend in amylose content (Table 8). Amylose content of fresh cassava starch were reported to range between 22.6-26.2% for five cassava varieties (Moorthy *et al.*, 1992). When the amylose content of six varieties of cassava was compared during growth period, there were insignificant differences among the varieties (Moorthy, 1994). Barimah (1999) reported amylose content of starch from dry chips ranging between 22.3-24.5% for the varieties *Afisiafi*, *Abasafitaa*, *Gblemoduade* and *Isu-white*. These values were obtained for varieties at one particular age. On the other hand, Rickard *et al.* (1991) reported amylose content of 13.6-23.8%. Amylose

content obtained in this study were high probably because of the presence of amylose-like substances produced by the hydrolytic action of both endogenous and microbial amylolytic enzymes on the amylopectin in the cassava mash during its processing into flour. Neither age nor variety significantly affected ($p>0.05$) amylose content.

Swelling power. Swelling power of *Afisiafi* ranged between 17.2-28.0 with the lower and upper limits at 13 and 9 months, respectively. For *Tek bankye* the values were 18.1-31.1, with the lowest value at 12 months and the highest at 9 months after planting. *Abasafitaa* had swelling power in the range of 20.7-28.5 with the lower and upper limits at 11 and 15 months respectively, while *Gblemoduade* had values between 18.7-32.0 with the lowest value at 11 months and highest value at 13 months. *Tek bankye* had its swelling power falling sequentially from a peak at 9 months till 12 months after planting, after which it began to rise (Table 9). No significant difference ($p>0.05$)

Table 7: Starch yield of flour from four cassava varieties at different ages.

Starch Yield	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	53.60 (0.05)	71.55 (0.47)	68.46 (0.18)	70.36 (0.23)
10 months	75.50 (1.01)	67.33 (0.13)	71.24 (0.20)	69.95 (0.37)
11 months	63.94 (0.18)	73.65 (0.14)	64.06 (0.89)	68.16 (0.22)
12 months	72.40 (0.09)	71.72 (0.03)	72.93 (0.24)	75.35 (0.03)
13 months	69.63 (0.85)	73.83 (0.07)	74.24 (0.03)	76.01 (0.13)
14 months	66.19 (0.65)	72.45 (0.43)	75.69 (0.15)	63.75 (0.06)
15 months	67.71	73.45 (0.25)	68.63 (0.27)	73.87 (0.03)

Table 8: Amylose content of flour from four cassava varieties at different ages.

Amylose	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	16.48 (0.00)	21.71 (0.00)	36.00 (0.00)	34.57 (0.00)
10 months	22.19 (0.00)	36.00 (0.00)	30.29 (0.00)	34.57 (0.00)
11 months	30.29 (0.00)	26.48 (0.00)	32.19 (0.00)	28.86 (0.00)
12 months	34.57 (0.00)	31.71 (0.00)	23.14 (0.00)	23.62 (0.00)
13 months	26.00 (0.00)	23.62 (0.00)	27.43 (0.00)	23.14 (0.00)
14 months	20.29 (0.00)	20.29 (0.00)	20.76 (0.00)	34.57 (0.00)
15 months	23.49	22.67 (0.00)	23.14 (0.00)	34.57 (0.00)

existed between ages and varieties. There was a positive correlation between swelling power and peak temperature for *Abasafitaa* ($r^2=0.509$) and *Gblemoduade* ($r^2=0.883$). Barimah (1999) reported a strong correlation between swelling power and peak viscosity for starch from dried cassava chips, while Balagopalan *et al.* (1988) also reported that starches capable of high swelling are less resistant to break down. Even though there was a relationship between swelling power and peak viscosity for *Afisiayi* and *Tek bankye*, correlation between them was weak ($r^2=0.378$ & 0.135 respectively). Similarly, a relationship with weak correlation existed between swelling power and paste breakdown for *Afisiayi*, *Tek bankye* and *Abasafitaa*. There was a very weak correlation ($r^2=0.134$) between starch yield and swelling power for *Gblemoduade*.

Solubility . The solubility of *Afisiayi* ranged between 8.1-17.4% with the lowest value at 12 months and the highest at 14 months, while for *Tek bankye* it was between 7.8-11.9%, with the lower and upper limits respectively at 11 and 14 months. *Abasafitaa* also had solubility values ranging between 13.1-18.7%, with the lowest value at 11 months and the highest at 9 months, while *Gblemoduade* had solubility between 11.7-18.8% with 11 and 12 months having the lowest and highest values respectively. With the exception of *Afisiayi*, all other varieties had lowest values at 11 months after planting. *Tek bankye* had the lowest solubility values, followed by *Afisiayi* and then *Gblemoduade*, while *Abasafitaa* had the highest solubility values. Barimah (1999),

working on four cassava varieties: *Afisiayi*, *Isu-white*, *Abasafitaa* and *Gblemoduade*, reported solubility values between 9.6-14.7% for starch obtained from fresh tubers, with the lower and upper limits representing *Gblemoduade* and *Abasafitaa* respectively. For starch from dried cassava chips, Barimah (1999) reported values between 11.4-19.7%, representing *Gblemoduade* and *Abasafitaa* respectively. The values obtained in this study (Table 10) compare well with those reported by Barimah (1999).

There was no significant difference ($p>0.05$) in solubility between ages, but significant difference ($p<0.05$) existed among varieties. There was weak correlation ($r^2=0.447$ and 0.285 , respectively) between moisture content and solubility for *Tek bankye* and *Gblemoduade*. *Gblemoduade* showed correlation ($r^2=0.502$) between starch yield and solubility while *Afisiayi* showed correlation ($r^2=0.518$) between amylose content and solubility. Swelling power also correlated ($r^2=0.658$, 0.428 and 0.568 , respectively) with solubility for *Tek bankye*, *Abasafitaa* and *Gblemoduade*. It is expected that high solubility flour gelatinizes at low temperature since water readily enters its starch granules resulting in easy solubilization and subsequent gelatinization upon heating. However, *Afisiayi* showed a weak correlation ($r^2=0.305$) between solubility and gel temperature while that for *Tek bankye* was strong ($r^2=0.828$). Peak temperature also correlated with solubility for both *Afisiayi* ($r^2=0.664$) and *Tek bankye* ($r^2=0.787$). Even though solubility showed a relationship with

Table 9: Swelling power of flour from four cassava varieties at different ages.

Swelling Power	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	28.95 (0.15)	31.07 (0.35)	24.26 (0.54)	30.40 (0.25)
10 months	27.80 (0.35)	25.21 (0.07)	21.92 (0.28)	31.65 (0.07)
11 months	20.30 (0.31)	21.98 (0.21)	20.71 (0.14)	18.74 (0.23)
12 months	28.41 (0.09)	18.13 (0.13)	26.10 (0.14)	30.08 (0.27)
13 months	17.15 (0.17)	26.61 (0.29)	28.23 (0.19)	31.97 (0.21)
14 months	27.24 (0.39)	29.85 (0.38)	21.41 (0.40)	28.03 (0.38)
15 months	27.40	30.39 (0.34)	28.45 (0.16)	26.16 (0.24)

both paste breakdown and retrogradation, correlation was weak. There is therefore a clear indication that starch loss during processing affected the relationship between solubility and other functional properties such as pasting characteristics.

Pasting characteristics. Pasting temperature of *Afisiafi* ranged between 67.7-70°C with the lower limit at 15 months and the upper limit at 13 months; *Tek bankye* had values between 68.7-73.2°C representing 10 months and 11 months respectively. *Abasafitaa* had values between 69-71°C, representing 15 and 11 months respectively, while *Gblemoduade* also had pasting temperatures in the range of 68-71°C, representing 15 and 11 months respectively. There was no significant difference in pasting temperature between ages but significant difference ($p < 0.05$) existed among varieties (Table 11).

Gelatinization temperature was recorded as the temperature at which paste viscosity rose from 0 to 20BU. This temperature was attained after pasting temperature had been recorded. Gelatinization temperature of *Afisiafi* ranged between 69.7-75.3°C with the lower and upper limits respectively at 9 and 13 months, while *Tek bankye* had values between 70.15°C (14 months) and 78.6°C (11 months). *Abasafitaa* also had its gelatinization temperature in the range of 70.8°C (13 months) and 76.0°C (11 months), while *Gblemoduade* had values between 69.3°C and 75.3°C, with the lowest and highest values at 13 and 11 months after planting respectively. Both *Abasafitaa* and *Gblemoduade* had lowest and highest values respectively at 13 and 11 months after planting. There was no significant difference ($p > 0.05$) between ages, but significant

Table 10: Solubility of flour from four cassava varieties at different ages.

Solubility	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	12.73 (0.03)	10.37 (0.01)	18.65 (0.01)	16.87 (0.01)
10 months	12.85 (0.01)	10.37 (0.01)	15.27 (0.03)	16.33 (0.00)
11 months	10.70 (0.01)	7.81 (0.00)	13.11 (0.01)	11.72 (0.01)
12 months	8.02 (0.01)	8.84 (0.02)	14.87 (0.01)	18.80 (0.04)
13 months	8.58 (0.00)	10.04 (0.00)	17.06 (0.01)	16.22 (0.00)
14 months	17.42 (0.01)	11.89 (0.01)	13.44 (0.01)	12.38 (0.01)
15 months	12.61	11.86 (0.00)	16.91 (0.01)	14.57 (0.01)

LSD for variety = 2.18.

Table 11: Pasting temperature of flour from four cassava varieties at different ages.

Pasting Temperature	<i>Afisiafi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	67.85 (1.20)	72.80 (2.69)	70.45 (0.49)	68.25 (0.35)
10 months	69.25 (0.78)	68.70 (0.28)	70.15 (1.63)	69.80 (0.14)
11 months	68.05 (0.07)	73.20 (1.84)	71.00 (0.71)	71.00 (0.00)
12 months	69.55 (0.92)	71.05 (0.64)	69.80 (0.42)	70.50 (0.42)
13 months	69.95 (0.92)	69.80 (1.41)	69.60 (0.57)	68.55 (0.49)
14 months	69.10 (0.00)	69.10 (0.14)	69.00 (0.14)	68.80 (0.28)
15 months	67.69	69.50 (0.00)	68.95 (1.34)	68.00 (0.00)

LSD for variety = 1.03.

difference ($p < 0.05$) existed among varieties for gelatinization temperature (Table 12).

Peak temperature. Peak temperature for *Afisiifi* was between 82.2-89.2°C with 14 and 13 months having the lowest and highest values respectively, while *Tek bankye* had values between 82.6-91.1°C with the lower and upper limits at 14 and 11 months after planting respectively. *Abasafitaa* had peak temperatures ranging from 80.7-90.7°C with 13 and 11 months having the lowest and highest values respectively, while *Gblemoduade* also had values ranging from 77.6-92.1°C with the lowest value at 13 months and the highest at 11 months old.

Both *Afisiifi* and *Tek bankye* had their lowest peak temperatures at 14 months after planting, while *Abasafitaa* and *Gblemoduade* had their lowest and highest values at 13 and 11 months after planting respectively. Apart

from *Afisiifi* whose upper limit for peak temperature was at 13 months, all the other varieties had their upper limits at 11 months after planting. There was no significant difference ($p > 0.05$) in peak temperature between ages but significant difference ($p < 0.05$) existed among varieties (Table 13). Barimah (1999) reported peak temperatures between 73.7-74.8°C for flour from the above-mentioned cassava varieties. However, values reported by Barimah (1999) are lower than that obtained in this study. The reason may be due to a difference in processing method; Barimah's flour was produced from dry chips while that used in this study were from dried, grated mash.

Aryee (2001) reported peak temperatures of cassava flour from thirty-one varieties to range between 73.1°C to 84.5°C; the age at harvest, however, was not reported. Other factors such as size and shape of starch

Table 12: Gelatinisation temperature of flour from four cassava varieties at different ages.

Gelatinization Temperature	<i>Afisiifi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	69.70 (1.13)	75.60 (0.99)	73.00 (0.85)	70.20 (0.00)
10 months	71.25 (0.64)	72.15 (0.49)	74.00 (0.71)	70.65 (0.21)
11 months	70.25 (0.07)	78.60 (0.57)	76.00 (0.71)	75.30 (0.14)
12 months	72.15 (0.07)	78.20 (0.28)	71.50 (0.28)	72.55 (0.92)
13 months	75.25 (1.34)	73.55 (1.06)	70.80 (0.28)	69.35 (0.07)
14 months	70.80 (0.42)	70.15 (0.07)	71.10 (0.28)	69.45 (0.07)
15 months	69.75	72.15 (0.07)	71.40 (0.99)	69.70 (0.00)

LSD for variety =1.88.

Table 13: Peak temperature of flour from four cassava varieties at different ages.

Peak Temperature	<i>Afisiifi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	83.55 (0.35)	89.05 (0.49)	88.30 (2.69)	80.35 (0.07)
10 months	85.50 (0.85)	86.10 (0.00)	88.55 (0.07)	78.80 (0.00)
11 months	84.10 (0.42)	91.05 (0.35)	90.75 (1.91)	92.10 (0.42)
12 months	86.55 (0.92)	90.60 (1.70)	84.65 (1.20)	80.25 (1.91)
13 months	89.20 (0.14)	87.05 (0.78)	80.70 (1.56)	77.60 (0.71)
14 months	82.20 (0.00)	82.60 (0.00)	83.80 (0.85)	78.40 (0.57)
15 months	83.98	85.85 (0.21)	84.00 (1.41)	81.65 (0.21)

LSD for variety =2.83.

granules may also affect the pasting, gelatinization and peak temperatures of flour.

Peak viscosity of *Afisiayi* was between 210-305BU with the lowest and highest values at 14 and 10 months respectively, while *Tek bankye* had values between 220-300BU with the lower and upper limits at 10 and 9 months respectively. *Abasafitaa* had peak viscosities between 145-225BU with the lowest and highest values at 10 and 12 months respectively, while *Gblemoduade* had values between 160-220BU, with the lowest value at 12 months and highest at 13, 14 and 15 months after planting. Peak viscosity was significantly affected ($p < 0.05$) by variety but not age (Table 14).

Hot paste breakdown for *Afisiayi* ranged between 60-85.3BU, with the lowest and highest values respectively at 11 and 15 months, while that of *Tek bankye* was between 60-105BU, with 10 months and 9 months having the lowest and highest values

respectively. *Abasafitaa* had values between 10-80BU, with the lowest at 9 months and the highest at 13 months while that of *Gblemoduade* was between 70BU (12 months) and 115BU (15 months). *Abasafitaa* had the lowest paste breakdown while *Gblemoduade* had the highest. Paste breakdown was significantly affected ($p < 0.05$) by variety but not by age (Table 15). There was a relationship with strong correlation ($r^2 = 0.717$ & 0.807 respectively) between paste breakdown and both amylose content and crude fibre for *Tek bankye*. A similar relationship with moderate correlation ($r^2 = 0.594$ & 0.593 respectively) existed between paste breakdown and both amylose content and crude fibre for *Abasafitaa*. As stated in the previous section, both amylose and fibre molecules (cellulose and hemicelluloses) interact with water molecules through hydrogen bonding, in an aqueous suspension of starch or flour when heated. This results in gelatinization and

Table 14: Peak viscosity of flour from four cassava varieties at different ages.

PeakViscosity	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	280 (14.14)	300 (0.00)	155 (7.07)	190 (0.00)
10 months	305 (7.07)	220 (14.14)	145 (7.07)	210 (0.00)
11 months	245 (7.07)	290 (0.00)	180 (14.14)	175 (7.07)
12 months	290 (0.00)	235 (7.07)	225 (7.07)	160 (14.14)
13 months	215 (7.07)	280 (14.14)	180 (14.14)	220 (0.00)
14 months	210 (0.00)	270 (0.00)	210 (0.00)	220 (0.00)
15 months	261	250 (0.00)	185 (21.21)	220 (0.00)

LSD for variety =31.86.

Table 15: Hot paste breakdown of flour from four cassava varieties at different ages.

Breakdown	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	75	105	10	80
10 months	85	60	40	95
11 months	60	90	50	85
12 months	70	80	75	70
13 months	70	80	80	105
14 months	80	100	60	110
15 months	85	85	65	115

LSD for variety =15.63.

subsequent increase in the viscosity of the paste. When the hot paste is agitated for a long period at high temperature, as is caused by the rotation of the Brabender amylograph bowl, the weak hydrogen bonds between some of the amylose molecules and water molecules break and the amylose molecules coil up forming intramolecular and intermolecular hydrogen bonds within and between its molecules. This causes a sharp decrease in viscosity and a consequent breakdown of the hot paste. The hydrogen bonds between cellulose or hemicelluloses and water molecules may also break in a similar manner causing hot paste breakdown.

Retrogradation profile of *Afisiayi* started at 9 months with a value of 40BU and rose to 50BU at 10 months from where it fell to 0 (zero) at 11 months. It then rose to 30BU at 12 months but fell again to 5BU at 13 months and remained there till 14 months, from where it rose to 12.2BU at 15 months after planting. *Tek bankye*, on the other hand, started from 45BU at 9 months and fell to 10BU at 10 months, but rose to 20BU at 11 months. It fell again to 15BU at 12 months, rose to 20BU at 13 months and fell to 5BU at 14 and 15 months after planting. *Abasafitaa* and *Gblemoduade* had their retrogradation values between -5BU and 10BU. *Afisiayi* and *Tek bankye* therefore had high values for retrogradation while *Abasafitaa* and *Gblemoduade* had low values. Retrogradation was significantly affected ($p < 0.05$) by variety but not by age (Table 16).

Conclusion

Age had significant effect on yield, moisture, ash and crude protein, while variety significantly affected solubility, flour yield and all the pasting characteristics. To obtain optimum flour yield from *Afisiayi* and *Tek bankye*, harvesting should be done at 13 months after planting while for *Abasafitaa* and *Gblemoduade*, harvesting should be at 12 months after planting.

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Table 16: Retrogradation or setback of flour from four cassava varieties at different ages..

Retrogradation	<i>Afisiayi</i>	<i>Tek bankye</i>	<i>Abasafitaa</i>	<i>Gblemoduade</i>
9 months	40	45	0	5
10 months	50	10	5	0
11 months	0	20	5	0
12 months	30	15	5	10
13 months	5	20	0	-5
14 months	5	5	0	0
15 months	12	5	-5	-5

LSD for variety =10.20.

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Genome organization and molecular variability in Sweetpotato chlorotic fleck virus

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Abstract. The complete nucleotide sequence of the genomic RNA of a Ugandan isolate of Sweetpotato chlorotic fleck virus (SPCFV) was shown to be 9104 nt. The SPCFV RNA not only is very similar in genomic organisation to that of carlaviruses but also encodes proteins that showed strong homologies with those of carlaviruses. Open reading frame (ORF) 1 codes for a 238 kDa protein with characteristic motifs of replication-associated proteins. ORFs 2, 3 and 4 code for proteins of 27.5, 11.5, and 7.3 kDa, respectively, that form the multifunctional triple gene block proteins. ORF 5 encodes the capsid protein (CP) of 33 kDa and ORF 6 a 15-kDa protein with a nucleic acid binding zinc finger motif (NBP). Comparison with other carlaviruses showed 12-40% similarities. Based on CP sequences, the closest relatives of SPCFV among carlaviruses are Shallot latent virus (36.2%) and Kalanchoe latent virus (37.1%). However, the SPCFV genome (9.1 kb) differs from typical carlaviruses (7.4 - 8.5 kb) by being considerably larger as a result of a larger ORF 1 (238 vs. 200-223 kDa) and a long untranslated region between ORF 4 and 5 (213 vs. ca. 34 nt for Potato virus M). To obtain a better understanding of the molecular variability of the SPCFV genome, about 2000 nts of the 3' terminal genome part of a range of geographically diverse isolates were sequenced. Comparison of the deduced amino acid sequences revealed a considerable level of geographically associated diversity among SPCFV isolates. The CP and NBP amino acid sequence similarities ranged from 88 to 100 %

and from 75 to 99%, respectively. In phylogenetic analysis of CP amino acid sequences, a major East African cluster with 92-99% intragroup identity and a non-East African cluster with 88-91% intragroup identity became evident.

Introduction

Since the first report of its isolation at International Potato Center (CIP) in 1992, Sweetpotato chlorotic fleck virus (SPCFV) has been reported from several countries including Uganda, Kenya, Peru, Japan, Cuba, Panama, Bolivia, Colombia, Brazil, Philippines, Indonesia (CIP, 1992; Fuentes and Salazar 1992; Salazar and Fuentes, 2000) and China, Taiwan and North Korea (this study). Available information from electron microscope observations indicates that the virus has filamentous particles measuring 750-800 by 12 nm, encapsidated by a capsid polypeptide of Mr 33.5 kDa (CIP, 1992; Fuentes and Salazar, 1992). Limited host range studies suggest that SPCFV has a narrow host range in the families of *Convolvulaceae* and *Chenopodiaceae* (CIP, 1992, Fuentes and Salazar, 1992). SPCFV is mostly symptomless in its natural host, hence, it was also referred to as sweetpotato symptomless virus in Japan (CIP, 1992). Based on ELISA results, SPCFV appeared to be unrelated to a number of known filamentous viruses infecting sweetpotato including *Sweetpotato feathery mottle potyvirus* (SPFMV), *Sweetpotato mild mottle ipomovirus* (SPMMV), *Sweetpotato*

chlorotic stunt crinivirus (SPCSV), *Sweetpotato latent potyvirus* (SPLV), *Sweetpotato mild speckling potyvirus* (SPMSV) and C-6 virus (Wambugu, 1991).

Despite the apparently wide geographic distribution, SPCFV has remained poorly characterised and unclassified. However, because of closeness in size of the filamentous particles SPCFV was thought to be a potyvirus (Fuentes and Salazar, 1992). To extend the available findings and more precisely describe the properties of SPCFV that would enable ascertaining of its taxonomic position, the complete nucleotide sequence of a Ugandan isolate of SPCFV was generated in this study. Additional data were obtained from the 3' terminal genome part of a range of geographically diverse isolates. These were sequenced in order to obtain a better understanding of the molecular variability of the SPCFV genome. Sequence analysis of the entire genome provided ambiguous evidence for the assignment of SPCFV as a distinct species to the genus *Carlavirus*. Our study also revealed a considerable level of geographically associated molecular diversity among strains of SPCFV infecting sweetpotatoes in the world.

Materials and Methods

Cloning strategy. To minimize the risk of unintentional mixed infection, a SPCFV isolate Hoima 4 was selected originating from an accession from Hoima district in Uganda, which in DAS-ELISA (Clark and Adams, 1976) showed a mixed infection only with SPCFV and SPCSV. By mechanical inoculation, SPCSV was eliminated and a pure isolate of SPCFV obtained and maintained by further successive mechanical passage on *Nicotiana occidentalis* subsp. *obliqua*. The generation of the complete genome sequence of SPCFV then followed a series of integrated steps but generally it included production of purified virions using a modified protocol of Lisa *et al.* (1981), followed by generation of the genome fragments using a random PCR (rPCR) method (Froussard, 1992), filling of gaps up-

and down-stream the random PCR generated clones using colony lift hybridization and RT-PCR and finally generation of the 5'- and 3'-terminal regions using Rapid Amplification of cDNA Ends (RACE) method (Frohman *et al.*, 1988) with primers proximal to each region.

Random PCR. Total RNA (TRNA) was extracted from the purified virions using the NucleoSpin^a RNA Plant kit (MACHEREY-NAGEL GmbH & Co., Germany). cDNA library and gemone fragments were generated from the TRNA using the random PCR (rPCR) method. Briefly, first strand cDNA was synthesised using a Universal primer-dN₆ (UN-RH) (Froussard, 1992) and RevertAidTM Moloney Murine Leukaemia Virus Reverse transcriptase (MMLV-RT, Promega, Madison WI, USA). RNase H¹ (Promega, Madison WI, USA) was included in the reaction to get rid of unincorporated RNAs. The second strand was then synthesized using Klenow DNA polymerase (Promega) according to manufacturer's instructions. PCR was performed on the same as for RT-PCR using Tag polymerase and universal primer, UN (Froussard, 1992) under the following thermal cycling profiles: preliminary denaturing step of 2 min at 94^o C, and then followed by 29 cycles of 1 min at 94^o C, 1 min at 60^oC, 3 min at 72^oC before a 5 min final extension at the same temperature as before.

RT-PCR. After were preparing cDNAs using MMLV-RT, PCR was performed using a proof reading DNA polymerase (Proof sprinterTM Tag/Pwo Mix, HYBAID-AGS, Germany) in a mixture comprising 41.3µl H₂O, 0.5 µl Tween 20 (10%), 1.0 µl DMSO, 5µl x10 buffer (complete), 0.4 µl dNTP (25 mM each), 0.5 µl Tag/Pwo Mix (5 U/µl) and 0.5 µl (100 mM) each of the sense and antisense primers. The PCR cycling parameters followed as: activation of polymerase at 94^o C for 4 minutes followed by 29 reaction cycles of denaturation at 94^o C for 30 s, primer annealing at 55^oC for 1 min and DNA extension at 72^oC for 50 s. The final extension step was 72^o C for 7 min.

Comparison of 3'-terminal regions.

Generation of 3'-terminal regions: A total of 15 isolates from geographically diverse regions were tested (Table 1). The isolates were Hoima4, Hoima 3c, Kiboga 6b, Mpigi 6b, KBL38, Rukingiri 1a from Uganda; Njoro2, 91/15 and Njoro2 from Kenya; SPCFV-CIP from CIP Peru; Guangzhou1 from China, Le-97-598 from North Korea, TN340 from Taiwan, TN399 and of unknown origins. Total nucleic acids were extracted from fresh leaf tissues using Silica Capture method of Rott and Jelkamann (2001). RT-PCR was performed as before by using SPCFV uniUp1 (GCTTGTATGCCACCGCTGT) designed from the 3'-terminal region of Hoima4 genome as a sense primer and oligo(dT)₁₈ as the antisense primer. Where this pair of primer failed, isolate specific primers were used. Virions of isolate TN340 were purified from frozen leaves of *N. occidentalis* subsp *obliqua* using a modified protocol formerly described by Lisa *et al.* (1981).

Cloning, sequencing and analysis. PCR fragments generated were excised following electrophoresis in 1 µg/ml ethidium bromide stained 1% agarose gel, purified using the NucleoSpin[®] Extract kit (MACHEREY-NAGEL GmbH & Co., Germany), ligated into the multiple cloning site of pGM-T vector (Promega) and cloned into competent DH5a *E. coli* strain (Promega). Recombinant plasmid DNAs were purified from bacterial cells using NucleoSpin[®] Plasmid kit (MACHEREY-NAGEL GmbH & Co., Germany), and sequenced commercially (MWG-Biotech, D-85560 Ebersberg, Germany) in both orientations. Nucleic acid and deduced amino acid products were analysed using DNAMAN, Version 4.02, program (Lynnon Biosoft Copyright 1994-1998, Canada). Searches for similarities with other viral sequences from the GenBank and EMBL databases were done with BLAST (Altschul *et al.*, 1997). Alignments were done with Clustal W and Phylogenetic analyses done using programs in PHYLIP version 3.6. Genetic distances between pairs of amino acid

sequences were constructed by a distance PROTDIST. The Phylogenetic trees were constructed by a distance method (NEIGHBOR) and 1000 bootstrap data sets and consensus trees generated by the programs SEQBOOT and Tree View (CONSENSE), respectively.

Phylogenetic analysis of the complete CP and ORF 6 encoding a 15-kDa protein with a nucleic acid binding zinc finger motif herein referred to as NaBP, and the nucleotide sequences of the untranslated region preceding the CP (cp-UTR) of the 15 isolates were performed using a Neighbor-Joining method of Saito and Nei (1987) in ClustALX (Version, 1.8.3). Confidence values were derived using 1000 bootstrapped data sets and the phylogenetic trees constructed in the DRAW N-J TREE option and visualized as a phylogram in TreeView (version 1.6.6).

Results

The sequence analysis revealed that excluding a poly(A) tail, SPCFV has a 9104 nt (+) RNA genome. Translation of the sequence revealed six putative open reading frames (ORFs) with a characteristic *Carlavirus* like genome arrangement (Figure 1) flanked by non-translated regions (NR) of 62 nt and 52 at the 5' and 3' end, respectively. ORF1 codes for a protein of 2090 aa and a M_r of 237.5 kDa. BLAST search (Altschul *et al.*, 1997) and comparisons with the Conserved Domains Database (CDD) (Marchler-Bauer *et al.*, 2002), NCBI website, revealed helicase and RNA dependent RNA polymerase functional domains in this ORF, suggesting it to be the viral replicase. ORFs 2, 3 and 4 that code for 27.3-, 11.5-, and 7.3-kDa polypeptides, respectively, form a triple gene block (TGB), encoding three viral proteins which are involved in cell-to-cell movement of a diverse range of filamentous and rod-shaped plant viruses (e.g., allexi-, carla-, potex-, pecluviruses). ORF5 has two possible start codons that respectively result into proteins of 41.2 kDa and 33 kDa. However, 33 kDa protein start codon has a more favourable

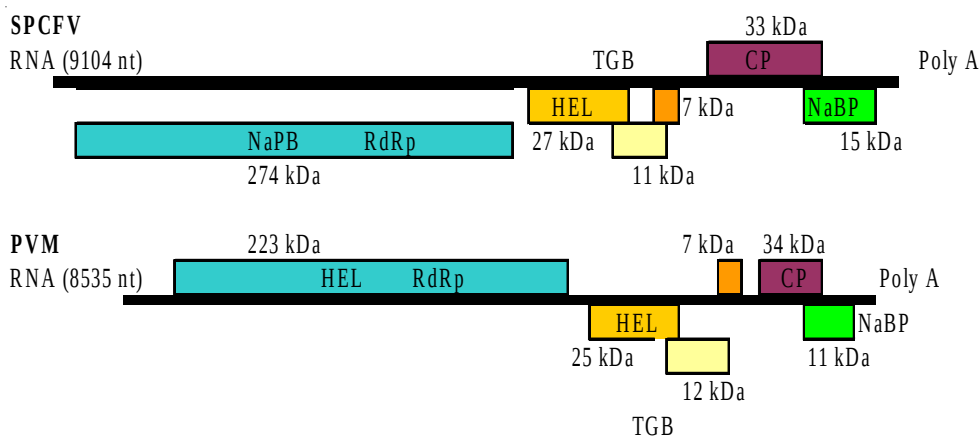


Figure 1: Genomic structure of the SPCFV and potato virus M RNAs. The boxes denote open reading frames and the numbers above or below the boxes indicate the molecular weights of potentially encoded proteins. HEL: helicase domain; RdRp: RNA-dependent RNA polymerase domain; TGB: Triple gene block proteins; CP: coat protein; NaBP: Nucleic acid binding protein.

initiation context and Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) and Western Blot analyses using purified virus preparations and leaf extracts from SPCFV-infected plants gave a coat protein size of ca. 33kDa, supporting the second start codon to be the proper CP start codon. Between ORF 4 and the SPCFV putative CP gene lies a 233 nt NTR which showed no obvious ORF. Seventeen nucleotides downstream ORF5 stop codon, ORF6 encodes a protein of M_r 15.3 kDa. A CDD search revealed a putative nucleic acid binding protein characteristic cysteine rich region of a zinc finger metal motif of carlaviruses (Gramstat *et al.*, 1990) in this ORF6.

Although, the putative TGB proteins of SPCFV showed strong similarities with membrane proteins of Carla-, Potex-, Fovea and Alexiviruses with a similarity percentage 20-40% lying within the range reported for these viruses (Gamble *et al.*, 2001), phylogenetic analyses of them did not allow a clear clustering of the individuals within the different genera. Therefore, to establish the phylogenetic relationship of SPCFV, its putative polymerase, coat and nucleic acid binding protein sequences were compared

with those of members of genera of the “triple gene block virus group”. In the phylogenetic analysis, the putative SPCFV polymerase clustered with that of carlaviruses (Figure 2). The highest similarities were found with carlaviruses (31.5%), *Lily latent virus*, (28.5%), *Blue berry scorch virus* (28%) and *Potato virus M*. Similarly, the phylogram of the coat protein sequences revealed clustering of SPCFV together with members of carlaviruses with *Shallot latent carlavirus* (36.2%) and *Kalonche latent carlavirus* (37.1%) as the closest relatives. The clustering of the putative nucleic acid binding protein did not properly confirm the phylogenetic position of SPCFV with carlaviruses (Figure 2) since the highest similarity was with vitivirus *Grapevine virus B* (31.7%) but lower similarities of 8.8-20% to carlaviruses.

The 15 isolates showed a wide variation both in their CP nucleotide (nt) and the corresponding amino acid (aa) sequences ranging from 75.1-99.3% and 88.3-99.7%, respectively. At aa level, the East African (EA) isolates were 94.0-99.7% similar while isolates of the non-East African (non-EA) origin were more divergent (88.3.0-96.7%). Whereas the Ugandan isolates had a fairly uniform variation, within Kenya isolate 94/1S was

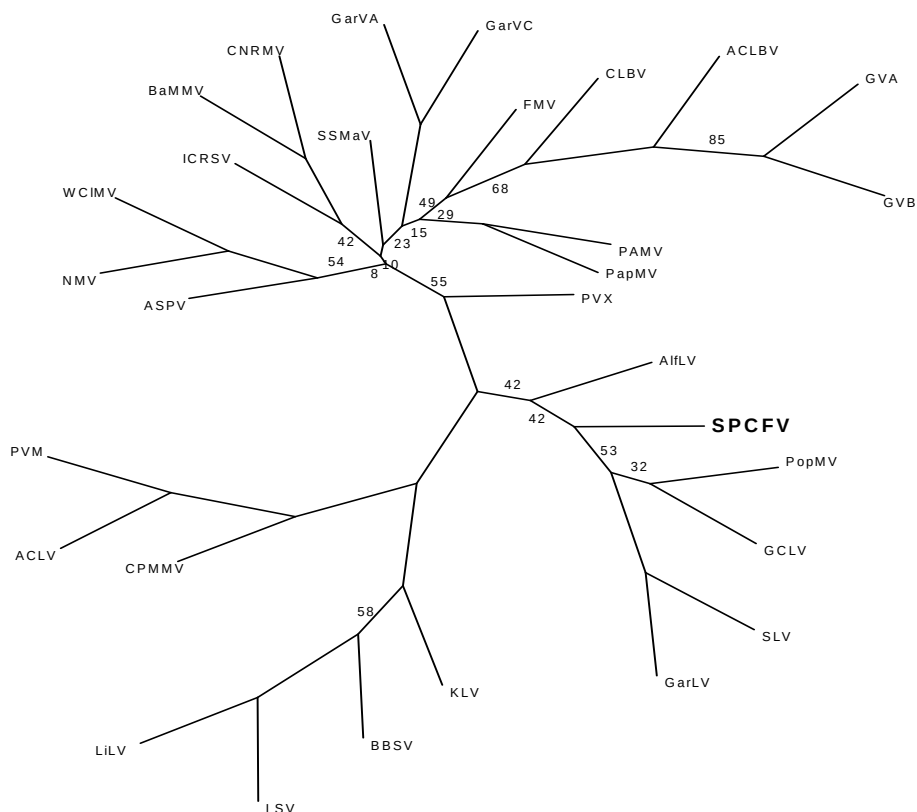


Figure 2: Unrooted phylogenetic tree based on amino acid sequences of CP of selected members of the "Triple gene block group viruses". Alignments and phylogenetic analyses were done using Clustal W and PHYLIP (version 3.6), respectively. One hundred bootstrap data sets were generated by the PHYLIP program SEQBOOT and genetic distances between pairs of amino acid sequences were constructed by PROTDIST (Kimura formula). Trees were generated using NEIGHBOR-JOINING) and CONSENSE and visualized using TreeView version 1.6.2. All bootstrap values exceed 90%, unless otherwise indicated. For details of virus names and groups, see text.

distantly related (<97%, aa) but closer to the Ugandan isolates (Table 2). Among isolates of non-EA origin, the SPCFV-type isolate from CIP was most similar to the EA isolates. Isolates Guangzhou1 from China, Le-97-589 from North Korea and TN399 of unknown origin had limited similarities to each other and to other isolates since they only showed 94.3-96.7% (aa) similarities. The least related isolates were TN340 from Taiwan and 07VIIMS of unknown origin that showed <91% (aa) similarity to other isolates. These two isolates were also considerably distantly related to each other (86.9% nt, 96.5% aa identical). Compared to the CP, the NaBP and cp-UTR

nucleotide and amino acid sequences were more variable.

Phylogenetic analysis of the CP aa sequences separated the SPCFV isolates into various clusters that corresponded to their geographical origin (Figure 3). Cluster I was formed by isolates from Uganda, Kenya, China and two isolates of unknown origin, while Cluster II, separated by a long genetic distance, was made up of an isolate from Taiwan and one isolate of unknown origin. Within cluster I, two subclusters were evident. Subcluster I was composed of Ugandan isolates, isolate 91/1S from Kenya and the SPCFV type isolate from CIP. Within this

subcluster, isolate Rukungiri 1a branched separately and appeared to be distinct from other isolates. Subcluster II was composed of isolates from Kenya, China and an isolate of unknown origin. The second major cluster formed by isolate TN340 and 007VIIMS had the least relationship to other isolates by about 90% identity and the two isolates were also separated from each other by a long distance. The phylogenetic trees generated from algorithms from the NaBP protein and cp-URT demonstrated the same overall topology.

Discussion

In this study, the complete nucleotide sequence of SPCFV was determined, and the analysis revealed extensive similarities between SPCFV and members of carlaviruses group. The array of six ORFs; a large 5' ORF 1 followed by a block of three overlapping proteins that form a triple gene block, the CP and a non-structural ORF with a characteristic Zinc finger motif at the 3' end, give SPCFV a characteristic organisation of the genus carlavirus (Hull, 2001). This was further supported by the presence of all conserved sequence motifs in translated regions of carlaviruses. There is only a limited (lower) sequence similarity with the members of the allexi-, fovea-, portex- and vitivirus groups with which the sequence showed similarity. The amino acid sequence of the CP of several carlaviruses have been determined and have been shown to contain two characteristic motifs; the N-terminally located KFAAFDxFx₂Vx₃AA motif (Dolja *et al.*, 1991) and the C-terminally located Dx₁₆₋₂₀TGG motif, suspected to be a catalytic motif for a threonine protease (Cavileer *et al.*, 1994). This study also showed that these two motifs were present in the 33kDa of SPCFV supporting the grouping of SPCFV with carlaviruses. In the SPCFV ORF6, the carlavirus characteristic zinc finger metal binding motif thought to function as viral transcriptional regulators was also present. The clustering of the SPCFV putative RdRp together with members of

carlaviruses, further, reinforced the observation made from the sequence comparisons that the sequence of SPCFV more closely resembles that of carlaviruses than to the members of the triple gene block group.

Although based on RdRp, CP and NaBP, SPCFV phylogenetically clustered together with carlavirus, it showed several differences that indicate that it is different from a typical carlavirus. The most significant of which is the comparatively long size of the RNA of SPCFV. The RNA of carlaviruses have lengths in the range of 6480-8535 nucleotides (Hull, 2001) with that of PVM being the longest (8535, Zavriev *et al.*, 1991). Therefore, the 9104 nt length of SPCFV isolate Hoima4 reported here is the longest carlavirus-related sequence reported to date. The long length of SPCFV results from the longer replicase 237.5 kDa compared to 200-2745 of carlaviruses and the long intergenic region (235 vs <50 nt) between the putative coat protein and TGB3 protein.

Analyses done on the nucleotide and amino acid sequences of the complete putative coat protein (ORF5), ORF6 encoding a 15 kDa protein with a characteristic zinc finger binding protein motif and the untranslated regions preceding the putative CP and the poly (A) tail of 15 SPCFV isolates provides the first data on the molecular variability of SPCFV infecting sweetpotatoes in the world. The CP amino acid identities among the 15 SPCFV isolates compared here varied widely, ranging from 88.3 to 99.7%. This pattern of variation is repeated in the NaBP, the cp-UTR and the 3'-UTR. Phylogenetic analysis of these regions revealed a clustering of the isolates into groups that correlated well with their geographical origins, suggesting a considerable level of geographically associated molecular diversity among strains of SPCFV infecting sweetpotatoes in the world. Two major groupings were formed. However, related to Cluster I by about 90% identity, Cluster II was formed by isolates that were separated from each other by a large genetic distance and shared <97% identity. This suggests that the current field situation

with SPCFV is complex and many more lineages may be revealed from further isolate analysis in the future. This points to the need to extend the current studies further and examine the extent of molecular variability among other a wider collection of SPCFV isolates.

The 7th International committee for taxonomy of viruses (ICTV) report has proposed that CP sequence similarities of the core region (i.e., excluding the N and C termini) of less than 68% are indicative of distinct carlavirus species and that strains of individual viruses have CP amino acid sequence identity ranging from 75-90% (Van Regenmortel *et al.*, 1997). Since the CP aa sequence similarities of the SPCFV isolates from East Africa, and isolates Guangzhou1, TN399 and Le-97-589 in Cluster I ranged from 94.0-99.7%, they should be considered to belong to the same strain of SPCFV. While the TN340 and 007VIIMS cluster with 96.3% intragroup identity that differed from cluster I by a 88.3-91% similarity suggests that the two isolates belong to another strain. This is supported by the sequences from each group being generated by group-specific primers. These two groups can be classified as i) the East African strain type that seem to be widely distributed, and ii) the Asia type that seem to be specific for Asian countries. Interestingly, although the isolates belong to two different strains, there were no differences observed in their biological features. Along with the fact that differential serological reactions of the antisera response was not observed in any of the three polyclonal antisera against isolate TN340, SPCFV-CIP and Hoima 4 (Aritua *et al.*, 2003), it is likely that the amino acid substitutions in CP do not easily result into changes in antigenic properties of the isolates or that the antigenic property and host range determining amino acids are conserved in SPCFV isolates. It could also be a reflection of the fact that the coat protein is not the gene responsible for symptom expression. A future functional analysis of the coding regions would better establish the role played if any by CP or other genes in symptom expression.

A broad variability of up to 81% in nucleotide sequence was documented when ordinary, Andean and central European isolates of Potato virus S were compared using the C-terminal part of the replicase, the coat and the 11-kDa proteins (Foster, 1991 and Matoušek *et al.*, 2000). Due to broad variability, isolates specific primers were used for the generation of the various regions of the PSV isolates (Matoušek *et al.*, 2000), a similar situation experienced in this study where a successful amplification of the 3'-terminal regions of isolates TNA340 and 007VIIMS were only possible with specific primers to each. Most recently, Choi and Ryua (2003) also revealed high heterogeneity in the 220 kDa protein of a Korean isolate of *Lily symptomless carlavirus* (LSV) encoding the polymerase associated protein and concluded that the LSV-infecting lily plants contained a genetically heterogeneous population. Although there is currently limited information of the extent of diversity among carlavirus species, a broad variability seem to be characteristic for them, therefore, the current variability shown by the three regions compared for SPCFV in this study further supports the motion for assignment of SPCFV as a carlavirus species (Aritua *et al.*, 2003).

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Soil nutrient and cassava yield variations under continuous cultivation of three-crop mixtures in Eastern Nigeria

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Abstract. A research farm at UNN which was under cultivation for >25 yrs before it was fallowed for 8 yrs, was cleared in 1998 and grown to three common crop mixtures for four years. The aim was to assess the performance of the cassava component under continuous cultivation relative to soil nutrient variations. The crop mixtures were cassava + pigeon pea, cassava + pigeon pea + maize, and cassava + pigeon pea + maize + yam. Incorporation of crop residues from each of the respective plots into the soils and the use of a legume (pigeon pea) served as means of restoring soil fertility. The experimental design was a randomized complete design (RCBD) replicated thrice each year. Changes in eight selected soil fertility indicators were monitored for the period. An analysis of the nutrient contents in the soils under the crop mixtures indicated narrow variations over the four years except in the cases of exchangeable cations where coefficients of variations of $\geq 25\%$ were obtained. Comparatively, year-to-year variations were more substantial though not consistent. This is because in some years some nutrients decreased while others increased relative to the values obtained in the preceding year. Except in 1999 when cassava root yields from all the crop mixtures decreased substantially (>60%) relative to their 1998 respective values, the trends in other years were not consistent in all the crop mixtures. The mean yields obtained were generally below the expected mean yield for the same cassava variety in the area. The study also showed that all the soil parameters

selected contributed to the variations in cassava yields though they were not consistent in each year and in each crop mixture. Thus, adequate management of these soil factors is required to enhance the performance of cassava in the crop mixtures.

Introduction

Intercropping (polyculture) is a well-known cropping system practised by most farmers in South Eastern Nigeria (SEN) for the production of most staple crops. The most popular crops found in mixtures are yam (*Dioscorea rotundata*), cassava (*Manihot esculenta*), maize (*Zea mays*) and pigeon pea (*Cajanus cajan*). The farmers generally adopt the intercropping (mixed cropping) system, with no special sequence of planting the crops. More than 70% of the food grown in the humid tropics, especially in Africa, comes from intercropping (IITA, 1984). In SEN about 80% of the farmers grow their crops in mixtures (Okigbo, 1978; Okorji, 1986). The numerous advantages of the system over sole cropping are well documented (Andrew, 1972; Finlay, 1974; Okigbo, 1978; Kantor, 1999) and appreciated by the farmers of SEN (Okorji, 1986; Asadu, 1997). Generally, yam- and cassava- based systems are the most popular among the farmers in SEN (Asadu, 1989). The importance of mixed cropping in the zone is hampered by shortened fallow periods or no fallow due to increasing population (Nweka *et al.*, 1994). The need for more and closer studies of the system especially with respect

to improving the soil management component for optimal yields and poverty alleviation is therefore imperative.

Most studies in the past on mixed cropping system have emphasized their advantages and constraints over sole cropping using yield parameters from component crops without due analysis of yield response to soil nutrient variations in the crop mixtures. The lack of information is more acute with respect to where continuous cultivation of the crop mixtures is practiced. The objectives of the study were to examine the yields of cassava from three crop mixtures under continuous cultivation as related variations in soil nutrients in the crop mixtures.

Materials and Methods

Study Location. The study was at the University of Nigeria, Nsukka (UNN) research farm fallowed for 8 years before the establishment of the trials in 1998. The soil has been classified as an alfisol (Asadu, 1990). Nsukka is located on Lat. 06° 52'N, Long. 07° 24'E within the derived savanna zone of SEN. It is on an average elevation of 447m above sea level. It usually has two seasons namely rainy and dry seasons. Average annual rainfall is about 1550 mm with more than 85% of this falling in the rainy season. The average minimum and maximum temperatures are about 22 and 30 °C respectively while the average relative humidity is rarely below 60%.

Crop mixtures and experimental design. Three crop mixtures were selected based on prior knowledge of the most common staple food crops grown by the local farmers in SEN: cassava + yam + maize + pigeon pea, cassava + maize + pigeon pea and cassava + pigeon pea. These crop treatments were arranged in a randomized complete block design and replicated three times for the four years beginning from 1998. Control sole crops were not included in this analysis because farmers in this area normally grow their crops in mixtures. The cassava variety used was TMS 30572, other crops were the local bests namely

Nwopoko for yam Western Yellow for maize and *ogam-gam* for pigeon pea.

The trials were established between 15 and 18 May each year. Cassava and yam were planted at a spacing of 1m x 1m on the tip of the ridges on May 15 and 16 while maize and pigeon pea were planted by the sides of the ridges at the same spacing on May 17 and 18 respectively. However, two seeds of maize and two seeds of pigeon pea were planted per hole following the local farmers' practice. The ridges were made with local hoes. In each location, an area of 20 m² at the centre of each plot was harvested for the analysis following the elimination of discards at the edges. Cassava yield parameters analyzed were root yield and harvest index (HI).

Soil sampling and analysis. During the four years of the experimentation loose soil samples were collected from each of the three replicate plots at 0-20 cm depth before cultivation commenced. These loose soil samples were air-dried gently, crushed and sieved with a 2-mm sieve. The samples were analysed to determine chemical properties. The soil pH was determined in duplicate in water using Beckman's zeromatic pH meter and in a soil: liquid suspension of 1:2.5. Exchangeable bases were extracted with neutral, 1N ammonium acetate (NH₄OAc) while Ca and Mg were determined by atomic absorption spectroscopy. Potassium (K) and Sodium (Na) were determined using flame photometry. Total nitrogen was determined by the macro-Kjedahl wet oxidation method (Bremner, 1965). Organic carbon was determined by the method of Walkley and Black (1934), and this was converted to soil organic matter (SOM) by multiplying the percentage carbon by 1.724. Available P was determined by Bray 2 method (Bray and Kurtz, 1945).

Data analysis. The percentage changes (p) in soil and cassava yield parameters between two-crop years were calculated from $p = 100 (Y_2 - Y_1) / Y_1$

where Y_1 = value of soil or cassava yield parameter in year 1

Y_2 = value of soil or cassava parameter in year 2 (year 1 precedes year 2 chronologically)

Results and Discussion

Soil Nutrient Variations. In cassava + pigeon pea (C+P) mixture, soil pH did not change substantially throughout the four year period. There was only a slight increase of about 2% (Table 1). There were increases in total N, SOM, exchangeable K, Ca and Mg in 1999 relative to the original values in 1998. On the other hand, available P and Na diminished in the reference years. All the fertility indicators except available P increased in 2000 relative to the 1999 values. Virtually all the nutrients except available P decreased in 2001 relative to the 2000 values. For the four years, only the exchangeable cations namely K, Ca, Mg and Na had coefficients of variation above 35%.

Table 2 also shows that in cassava + maize + pigeon pea mixture, soil pH did not vary substantially over the years. There was a slight decrease of 2% in 1999 relative to 1998 value while in 2000 and 2001 a slight increase of 2% each was obtained relative to the preceding years. Relative to the 1998 values, in 1999 there were increases in total N (H¹⁰%), SOM (H²⁶%), exchangeable Mg (H⁸⁶%) and exchangeable Ca (> 150%). Available P and exchangeable Na decreased by at least 30% while exchangeable K did not change (Table 2). In 2000 all the nutrients had increases except total N and available P which decreased by about 4% and 22% relative to the 1999 values respectively. Relative to the 2000 values, in 2001 there were increases in total N (H⁶%), SOM (H¹³%) and available P (H²⁰%). All the exchangeable cations decreased by at least 8% relative to the 2000 values (Table 2). For the four years, variations over 25% were obtained for all the exchangeable cations and available P (Table 2).

Table 1: Mean $\pm$ SD of soil fertility indicators obtained from 0-20 cm soil depth in C+ P mixtures and relative changes over four years (1998-2001) in eastern Nigeria.

Soil fertility indicators	Mean $\pm$ SD				Relative changes (%)				Overall mean (cv)
	1998	1999	2000	2001	1999 vs 1998	2000 vs 1999	2001 vs 2000	2001 vs 1998	
pH	4.6 $\pm$ 0.26	4.7 $\pm$ 0.20	4.8 $\pm$ 0.06	4.9 $\pm$ 0.00	+2.2	+2.1	+2.1	+6.8	4.8 (3)
Total N (%)	0.075 $\pm$ 0.02	0.092 $\pm$ 0.01	0.092 $\pm$ 0.01	0.092 $\pm$ 0.01	+22.7	+4.3	-4.2	+18.5	0.089 (11)
SOM (%)	1.22 $\pm$ 0.38	1.74 $\pm$ 0.08	2.09 $\pm$ 0.35	1.86 $\pm$ 0.14	+42.6	+20.1	-11.0	+52.5	1.73 (21)
Avail. P (mg kg ⁻¹)	7.0 $\pm$ 2.00	6.7 $\pm$ 0.58	5.3 $\pm$ 0.58	6.1 $\pm$ 0.00	-4.3	-20.9	+15.1	-12.9	6.3 (12)
Exc K (cmol kg ⁻¹)	0.06 $\pm$ 0.01	0.08 $\pm$ 0.03	0.13 $\pm$ 0.02	0.13 $\pm$ 0.01	+33.3	+62.5	0.0	+116.7	0.1 (36)
Exc Ca (cmol kg ⁻¹)	0.67 $\pm$ 0.21	2.10 $\pm$ 0.17	2.97 $\pm$ 0.85	1.93 $\pm$ 0.12	+213.4	+41.4	-35.0	+188.1	1.92 (49)
Exc Mg (cmol kg ⁻¹)	0.57 $\pm$ 0.21	1.37 $\pm$ 0.60	1.60 $\pm$ 0.36	1.27 $\pm$ 0.46	+140.4	+16.8	-20.6	+122.8	1.20 (37)
Exc Na (cmol kg ⁻¹)	0.15 $\pm$ 0.03	0.08 $\pm$ 0.03	0.26 $\pm$ 0.04	0.19 $\pm$ 0.02	-46.7	+223.0	-26.9	+26.7	0.17 (44)

Note: SD = standard deviation, cv = coefficient of variation (%), (+) = increase, (-) = decrease in the preceding year except in 2001 vs 1998

Table 2: Mean $\pm$ SD of soil fertility indicators obtained from 0-20 cm soil depth in C+ M + P mixtures and relative changes over four years (1998-2001) in eastern Nigeria.

Soil fertility indicators	Mean $\pm$ SD				Relative changes (%)				Overall mean (cv)
	1998	1999	2000	2001	1999 vs 1998	2000 vs 1999	2001 vs 2000	2001 vs 1998	
pH	4.8 $\pm$ 0.15	4.7 $\pm$ 0.15	4.8 $\pm$ 0.1	4.9 $\pm$ 0.0	-2.1	+2.1	+2.1	+2.1	4.8(2)
Total N (%)	0.082 $\pm$ 0.02	0.090 $\pm$ 0.01	0.086 $\pm$ 0.01	0.091 $\pm$ 0.0	+9.8	-4.4	+5.8	+11.0	0.087(5)
SOM (%)	1.41 $\pm$ 0.38	1.77 $\pm$ 0.15	1.79 $\pm$ 0.07	2.02 $\pm$ 0.08	+25.5	+1.1	+12.8	+43.3	1.75(14)
Avail. P (mg kg ⁻¹)	8.7 $\pm$ 3.51	6.0 $\pm$ 1.00	4.7 $\pm$ 0.58	5.6 $\pm$ 0.46	-30.0	-21.7	+19.1	-35.6	6.3(28)
Exc K (cmol kg ⁻¹)	0.07 $\pm$ 0.00	0.07 $\pm$ 0.01	0.13 $\pm$ 0.02	0.12 $\pm$ 0.00	0.0	+85.7	-7.7	+71.4	0.10(33)
Exc Ca (cmol kg ⁻¹)	0.70 $\pm$ 0.20	2.03 $\pm$ 0.75	3.27 $\pm$ 1.62	1.97 $\pm$ 0.15	+190	+61.1	-39.8	+181.4	1.99(53)
Exc Mg (cmol kg ⁻¹)	0.70 $\pm$ 0.20	1.30 $\pm$ 0.52	1.47 $\pm$ 0.72	1.27 $\pm$ 0.50	+85.7	+13.1	+13.6	+81.4	1.19(28)
Exc Na (cmol kg ⁻¹)	0.14 $\pm$ 0.04	0.07 $\pm$ 0.03	0.26 $\pm$ 0.02	0.18 $\pm$ 0.00	-50.7	271.4	-30.5	+28.5	0.16(48)

Note: SD = standard deviation, cv = coefficient of variation (%), (+) = increase, (-) = decrease in the preceding year except in 2001 vs 1998.

From Table 3, soil pH also exhibited the least variation both between years and across the four years in the cassava + yam + maize + pigeon pea mixtures. In 1999 available P and exchangeable Na decreased by 17 % and 39 % respectively relative to the 1998 values. Except exchangeable K that did not change, there were increases in other nutrients ranging from about 22% in total N to > 200% in exchangeable Ca (Table 3). Relative to 1999 values, in 2000 all the exchangeable cations had substantial increases ranging from about 50% in exchangeable Mg to >200% in exchangeable Na. On the other hand, total N and SOM had slight decreases while exchangeable K did not change. Relative to 2000 values, in 2001 total N did not change whereas there were increases in SOM (about 13%) and exchangeable K (about 8%). Other nutrients decreased by at least 24% (Table 3). For the four years only exchangeable cations had variations of up to 30% the highest being 56% exhibited by exchangeable Ca.

Generally, the mean soil pH values in both 1998 and 1999 were acid (4.5 < pH < 5.0) based on the USDA-SCS (1974) classification. These values are generally below the range (5.2-7.0) recommended for cassava by the FAO (1998).

The mean values of total N in each year appeared to be low and below the critical levels for cassava (Metson, 1961; Enwezor *et al.*, 1989) irrespective of some observed increases. Similarly, the contents of SOM and available P appeared to be inadequate for the good performance of cassava each year based on the recommendation by Howeler (1996). The mean exchangeable K values obtained were generally below 0.2 cmol kg⁻¹, the critical level below which most crops will respond to K application (Meredith, 1965). The increases in exchangeable K obtained in 2000 under each crop mixture could be due to the incorporated crop residues since organic materials are also sources of K in soils (Asadu and Nweke, 1999). The mean values of exchangeable Ca obtained in each year appeared to be adequate since all are well above 0.2 cmol kg⁻¹, the critical level that will elicit Ca response by most crops (Meredith, 1965). Similarly all the values of

Table 3: Mean $\pm$ SD of soil fertility indicators obtained from 0-20 cm soil depth in C+M+P+Y mixtures and relative changes over four years (1998-2001) in eastern Nigeria.

Soil fertility indicators	Mean $\pm$ SD				Relative changes (%)			Overall mean (cv)
	1998	1999	2000	2001	1999 vs 1998	2000 vs 1999	2001 vs 2000	
pH	4.6 $\pm$ 0.35	4.6 $\pm$ 0.12	4.8 $\pm$ 0.06	4.9 $\pm$ 0.00	0.0	+4.3	+2.1	+6.5 4.7(3)
Total N (%)	0.076 $\pm$ 0.01	0.093 $\pm$ 0.01	0.092 $\pm$ 0.01	0.092 $\pm$ 0.00	+22.4	-1.1	0.0	+21.1 0.088(9)
SOM (%)	1.31 $\pm$ 0.23	1.91 $\pm$ 0.08	1.77 $\pm$ 0.21	2.00 $\pm$ 0.21	+45.8	-7.3	+13.0	+52.7 1.75(16)
Avail. P (mg kg ⁻¹)	9.3 $\pm$ 2.51	7.7 $\pm$ 1.15	7.7 $\pm$ 1.15	5.8 $\pm$ 0.46	-17.2	0.0	-24.7	-37.6 7.6(19)
Exc K (cmol kg ⁻¹)	0.07 $\pm$ 0.03	0.07 $\pm$ 0.02	0.12 $\pm$ 0.00	0.13 $\pm$ 0.00	0.0	+71.4	+8.3	+85.7 0.10(33)
Exc Ca (cmol kg ⁻¹)	0.63 $\pm$ 0.06	2.07 $\pm$ 0.75	3.52 $\pm$ 0.71	2.33 $\pm$ 0.42	+228.6	+70.5	-34.0	+269.8 2.14(56)
Exc Mg (cmol kg ⁻¹)	0.47 $\pm$ 0.12	1.27 $\pm$ 0.46	1.93 $\pm$ 0.11	1.23 $\pm$ 0.35	+170.2	+52.0	-36.3	+161.7 1.23(49)
Exc Na (cmol kg ⁻¹)	0.13 $\pm$ 0.03	0.08 $\pm$ 0.03	0.24 $\pm$ 0.04	0.18 $\pm$ 0.00	-38.5	+200.0	-25.0	+38.5 0.16(43)

Note: SD = standard deviation, cv = coefficient of variation (%), (+) = increase, (-) = decrease in the preceding year except in 2001 vs 1998.

exchangeable Mg were ≥ 0.5 cmol kg⁻¹ the critical level that will elicit Mg response by most crops (Landon, 1991). The increases in exchangeable Ca in 1999 and 2000 may also be attributed to the incorporated organic material from crop residues. The exchangeable Na contents in the soils were not high enough (>15% ESP) to induce deleterious effects on the crops (Landon, 1991).

The analysis of the cumulative variation (2001 vs 1998) shows that the order of enrichment of total N, exchangeable Ca, Mg and Na among the crop mixtures is C+M+P+Y>C+P>C+M+P (Tables 1-3). The order of SOM enrichment is almost the same, C+M+P+Y=C+P>C+M+P while that of exchangeable K is in the order C+P>C+M+Y+P>C+M+P. Only available P decreased over the four year comparison in the order C+M+Y+P>C+M+P>C+P. It is clear that the soil nutrient variations in the crop mixtures except in the cases of exchangeable K and available P were related to SOM dynamics, a relationship very much well known.

Cassava yields and soil nutrient variations.

The root yields obtained from the crop mixtures were not significantly affected by the number of crops in each mixture. The highest mean values obtained were at the beginning of the trials in 1998 (Table 4). These were the only values fairly close to that obtained using the same cassava variety (TMS 30572) in Nsukka environment (Nnodu *et al.*, 1995). The highest yield depressions (about 62-81%) occurred in 1999. The soil nutrient that might have accounted for these depressions was a decrease in the available P (Tables 1-3). The soil under C+M+P mixture with the highest decrease (30%) in available P (Table 2) produced the highest (80%) decrease in root yield (Table 4). The decrease in available P could have caused some negative nutrient interaction among other nutrients leading to a decreased root yield since available P is one of the major nutrients required by cassava in large amounts (Howeler, 1996).

The slight increases in cassava root yields (4%) in 2000 (Table 4) relative to the observations recorded in 1999 from C + P mixture might be attributed to slight increases in total N, SOM and all the exchangeable bases (Table 1). In the case of C + M + P mixture the observed yield increase (40%) is surprising because there was a substantial increase in exchangeable cations and only slight increase in SOM (Table 2). The 30% decrease in root yield obtained in C + M + P + Y mixture (Table 4) is also surprising because there were only slight decrease in total N and SOM in the reference years (Table 3).

The slight decrease in root yield in 2001 (Table 4) in C+P mixture is evident from the

slight decreases in total N and SOM as well as decreases in exchangeable Ca, Mg and Na (Table 1). On the other hand, the slight decrease in yield (about 9%) obtained from C+ M + P mixture might be associated with the observed decreases in all the exchangeable cations (Table 2). The increase in yield in C + P + M + Y mixture might be associated with the observed increases (Table 3) in total N (about 13%), and exchangeable K (about 8%).

In general, the results of the regression analyses between the relative root yields of cassava and the different changes in soil fertility indicators over the four years (Table 5) show that the most significant indicators

Table 4: Summary of cassava root yields and harvest index from the three crop mixtures and relative changes over four years (1998-2001) in eastern Nigeria.

Crop mixtures	Fresh root yield (t ha ⁻¹)				Relative changes (%)		
	1998	1999	2000	2001	1999 vs 1998	2000 vs 1999	2001 vs 2000
C + P	10.0	2.4	2.5	2.4	-76.0	+4.2	-5.1
C + M + P	11.9	2.3	3.2	2.9	-80.7	+39.1	-9.1
C + M + P +Y	8.4	3.1	2.2	4.0	-61.7	-29.0	+84.3
Harvest index							
C + P	0.67	0.63	0.55	0.61	-6.0	-12.7	+10.9
C + M + P	0.67	0.53	0.57	0.61	-23.2	+7.5	+7.0
C + M + P +Y	0.66	0.58	0.60	0.64	-12.1	+3.4	+6.7

Notes: C = cassava, M = maize, P = pigeon pea, Y = yam; (+) = increase, (-) = decrease in the preceding year.

Table 5: Regression parameters obtained between the relative root yields of cassava and relative changes in soil nutrients.

Soil parameter	Intercept	Slope	R ² /significant level
pH	-37.1	13.4	0.19 ^{ns}
Total N (%)	8.1	-3.7	0.51*
SOM (%)	7.9	-1.4	0.28 ^{ns}
Avail. P (mg kg ⁻¹)	-17.6	-0.3	<0.01 ^{ns}
Exc K (cmol kg ⁻¹)	-24.5	0.3	0.05 ^{ns}
Exc Ca (cmol kg ⁻¹)	15.5	-0.4	0.61**
Exc Mg (cmol kg ⁻¹)	16.0	-0.6	0.69***
Exc Na (cmol kg ⁻¹)	-22.5	0.1	0.13 ^{ns}

Note: ^{ns}, *, **, *** = not significant, significant at 0.05, 0.01 and < 0.001 probability levels respectively.

($p \leq 0.05$) are total N, exchangeable Ca and Mg as indicated by the R^2 values.

The changes in harvest index (HI) were generally small. However, there were consistent decreases between 1999 and 1998, and consistent increases between 2001 and 2000 (Table 4). The former may be associated with slight decrease in available P in C+P mixture, decreases in total N and available P in the C+M+P mixture and decreases in total N and SOM in the C+P+Y+Y mixture (Tables 1-3). The 13% decrease in HI in C + P mixture in 2000 could be due to the decrease in available P (Table 2). The slight increases in HI in 2000 relative to 1999 in the other two crop mixtures could be due to observed increases in all the exchangeable cations (Tables 2 and 3). Again the slight increases in HI in all the crop mixtures in 2001 relative to 2000 values (Table 4) could be due to an increase in available P in the case of C+P mixture (Table 1), increases in total N, SOM and available P in the case of C+P+M mixture (Table 2) and increases in SOM and available P in the case of C+P+M+Y mixture (Table 3).

Conclusion

An analysis of the variations in eight soil fertility indicators over four years in three crop mixtures in eastern Nigeria indicates that only the exchangeable cations namely K, Ca, Mg and Na varied substantially with cvs ranging from about 25% to 56%. However, year-to-year comparison indicated more substantial but inconsistent variations.

Cassava root yields decreased substantially (>60%) in all the crop mixtures in 1999 relative to the 1998 values. In 2000 there were slight increase (<5%) in C + P and large increase (about 40%) in C + P + M mixtures and up to 29% decrease in C + P + M + Y mixture relative to the 1999 values. On the other hand, the 2001 yields from C + P and C + P + M mixtures were above 90% of the respective yields obtained in 2000 indicating slight decreases where as there was an increase of about 80% in the C + P + M + Y mixture relative to the 2000 yield. The harvest index

decreased in all the crop mixtures in 1999 relative to the 1998 values and in the C+P mixture in 2000. There were slight increases in both C+M+P and C+M+P+Y mixtures in 2000 and in all the crop mixtures in 2001. Generally, the variations in cassava yields over the four years appeared to be associated with all the fertility indicators implying clear evidence of interactions among the nutrients. Thus these indicators need to be adequate in the soils for cassava to perform well in the crop mixtures.

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Characterization and variability of sweetpotato virus Y, a hitherto unrecognized potyvirus infecting sweetpotato in Southern Africa

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Abstract. The biological and molecular properties of a sweetpotato virus isolate formerly known as Sweetpotato virus 2 were determined. The virus had flexuous filamentous particles, induced cylindrical inclusions in infected cells and was experimentally transmitted by *Myzus persicae*. Sequence analysis of its coat protein and 3' non-translated region revealed that the virus is a distinct potyvirus, for which the name Sweetpotato virus Y (SPVY) is proposed. *Sweetpotato chlorotic stunt crinivirus* (SPCSV) synergized SPVY in *Ipomoea setosa* in mixed infections. Unlike plants that were infected only with SPVY or a Kenyan isolate (KY-38) of SPCSV and largely showed no symptoms, dually infected plants had significantly higher titres and a more uniform distribution of SPVY and showed conspicuous symptoms of SPVY infections. Comparisons of coat protein CP gene sequences of geographically diverse isolates of SPVY revealed amino acid sequence identities ranging from 86 to 100%. The results strongly suggest the existence of biologically and genetically diverse strains of SPVY from Southern Africa.

Introduction

Sweetpotato is an adaptable and versatile crop that has gained increasing importance as human food worldwide, particularly in developing countries. While in Africa the

major areas of sweetpotato production are concentrated in the Great Lakes region, sweetpotato is also important in several West African countries and in South Africa. Its presence and adaptation to the tropical areas, where the *per capita* income is generally low, and its nutritional value make this crop an important component in food production and consumption (CIP, 1996; CIP, 1998; Woolfe, 1992). However, the crop is faced with numerous production constraints including insect pests and diseases.

Virus diseases are the second most significant biotic constraint after the sweetpotato weevil (Geddes, 1990; Matin, 1999). Some of the viruses reported to infect sweetpotato such as Sweetpotato feathery mottle potyvirus (SPFMV) (Ryu *et al.*, 1998; Kreuze *et al.*, 2000), Sweetpotato chlorotic stunt crinivirus (SPCSV) (Gibson *et al.*, 1998), Sweetpotato mild mottle ipomovirus (SPMMV) (Hollings *et al.*, 1976), Cucumber mosaic cucumovirus (CMV) (Cohen and Loebenstein, 1991), Sweetpotato latent potyvirus (SwPLV) (Liao *et al.*, 1979; Colinet *et al.*, 1997), Sweetpotato potyvirus G (SPVG) (Colinet *et al.*, 1994), and Sweetpotato mild speckling potyvirus (SPMSV) (Alvarez *et al.*, 1997) have been characterized to a large extent and appear to cause severe viral diseases (Moyer and Salazar, 1989; Carey *et al.*, 1996; Karyeija *et al.*, 1998). However, the significance and taxonomic assignment of other virus isolates remain unclear.

In the early 80s, Rossel and Thottappilly (1988) succeeded in transmitting a potyvirus from sweetpotato to test plants. In *Nicotiana benthamiana* it induced mild vein yellowing followed by chlorotic mottle. This was unusual for an isolate of SPFMV at the time. Since the isolate also differed serologically from SPFMV, it was referred to as 'sweetpotato virus 2' (SPV2) (Rossel and Thottappilly, 1988). The SPV2 isolated from sweetpotato plants from Taiwan showed mild virus-like symptoms such as mottle, vein yellowing and/or ringspots but it did not cause any symptoms in some sweetpotato clones under experimental conditions (Rossel and Thottappilly, 1988).

The fact that this virus had remained incompletely described since the 80s, prompted us to further characterize it in order to generate a basis for its classification. The biological and molecular properties determined for SPV2 in this paper suggest that it is a distinct member of the genus Potyvirus.

Materials and Methods

Mixed infection with SPCSV. In 1989, the last author received a SPV2 isolate from G.Thottappilly, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and was maintained in *Nicotiana benthamiana*. The isolate was used to investigate the effect of SPCSV on SPV2 in *I. setosa*. The treatments comprised plants infected with SPV2 alone, plants infected with SPCSV only, plants dually infected with SPV2 and SPCSV, and non-inoculated control plants. Sixteen *I. setosa* plants were mechanically inoculated with SPV2. Seven days later, SPCSV-Ky38 was graft inoculated onto eight SPV2- infected and eight non-inoculated *I. setosa* plants which were about two weeks old. Eight non-inoculated *I. setosa* plants were included as a control. Symptom development was monitored and, at 21 days post inoculation, a composite sample of three symptomatic leaves was taken from each plant and analysed by DAS- and TAS-ELISA for SPV2 and SPCSV, respectively. Results

indicated that the plants were infected by the respective viruses used for inoculation. Since symptoms due to SPV2 were not uniformly distributed in SPV2-infected plants, three different leaf stages (bottom, intermediate, and top) were sampled from three randomly selected plants of each treatment and individually analyzed for SPV2 and SPCSV. Growth parameters such as leaf number, fresh shoot weight was determined for all the treatments and subjected to analysis of variance (ANOVA).

RNA extraction, RT- PCR and sequencing.

Total RNA was extracted from SPV2-infected leaves of *N. benthamiana* plants using the Nucleospin[®] Plant kit (Macherey-Nagel, Düren, Germany) following the manufacturer's instructions. Synthesis of complementary DNA (cDNA) from the 3' region of the viral genome was done using an oligo(dT) primer and M-MLV reverse transcriptase (GIBCO) according to the manufacturer's instructions. The 3' end of the SPV2 genome comprising part of the NlB gene, the coat protein gene and the 3'-nontranslated region (NTR) was amplified in a MJ Research (Massachusetts, USA) thermocycler using the potyvirus-specific, degenerate primers POT1 and POT2 of Colinet *et al.* (1994) as well as an oligo(dT) primer and the viral anti-sense primer 5'-TGAGGATCCTGGTGYATHGARAAYGG-3' (CPUP) of Langeveld *et al.* (1991). For determining the correct sequence of the 'WCIENG' region (binding site of the POT1 and CPUP primers), the SPV2 specific primers 5'-CGAACTTGCTCGAGTAGGCAG-3' (viral sense) and 5'-TCCGTCCATCATCACCCA-3' (viral anti-sense) were used. Cloning experiments into pGEM[®]-T vector (Promega) and transformations into *E. coli* strain DH5 α were conducted as described (Sambrook *et al.*, 1989). The CP nucleotide sequences of 12 other SPV2 isolates were also determined. DNA sequencing was done by a commercial company (MWG-Biotech, Ebersberg, Germany). Nucleotide and amino acid sequences were analysed and compared with NCBI databases using the basic local

alignment search tool (BLAST) programs (Altshul *et al.*, 1995).

Results

SPV2 caused more severe symptoms in mixed infections with SPCSV. *I. setosa* plants infected with SPV2 alone developed vein clearing and mosaic symptoms only on few leaves. These were, in general, the only leaves that had ELISA-detectable concentrations of SPV2, whereas the asymptomatic leaves of SPV2-inoculated plants tested negative in ELISA. The SPCSV alone caused nearly imperceptible symptoms in infected *I. setosa* and was reliably detected by ELISA in the intermediate and top leaves but not in the bottom leaves of infected plants (Table 1). However, plants co-infected with SPV2 and SPCSV showed very conspicuous symptoms on all leaves, such as severe veinal chlorosis, mosaic leaf distortions, leaf size reductions, and plant stunting.

In addition, the number of leaves and the fresh shoot weights of dually infected *I. setosa* plants were significantly ($P \leq 0.05$) lower

than those of singly infected plants, whose growth parameters were largely indistinguishable from each other and from those of non-inoculated plants (Figure 1). The SPV2 concentrations in plants infected only with SPV2 were often below the detection limit, particularly in the top leaves (Table 1). In dually infected plants, SPV2 attained higher concentrations and appeared to be more uniformly distributed than in singly infected plants. Unlike SPV2, the titre and distribution of SPCSV were only negligibly enhanced in dually infected plants as compared to singly infected plants (Table 1).

Sequence analyses and comparisons.

Sequence analysis of the 3'-terminal 2006 nucleotides of the SPV2 RNA (Acc. No. AY232437) showed that this genome fragment contains the coding sequence for the C-terminal half (296 aa) of the NIb protein and the entire CP (332 aa), which is followed by a 3' untranslated region (UTR) of 216 nucleotides (without the poly (A) tail). The coding sequence not only shared similarity with NIb and CP genes of potyviruses but

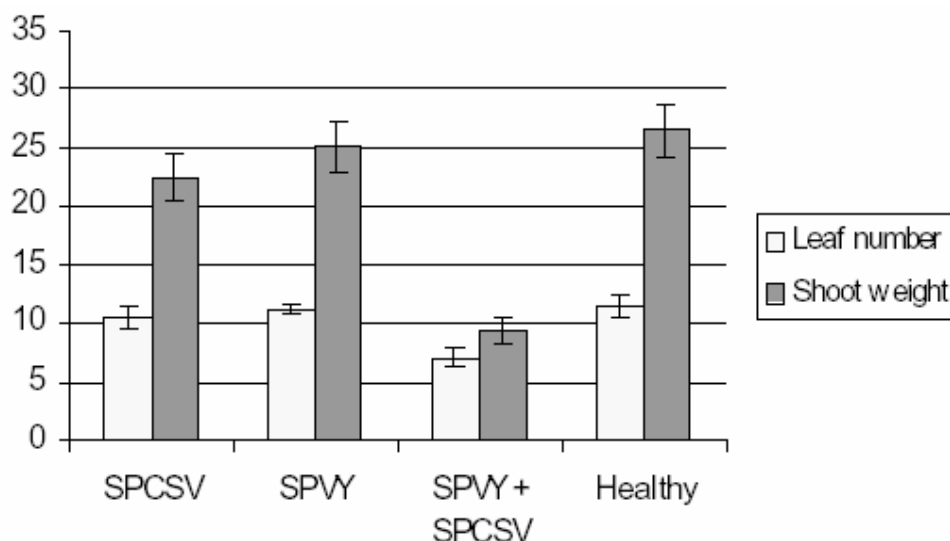


Figure 1: Leaf number and mean fresh shoot weight of plants inoculated with *Sweet potato chlorotic stunt virus* (SPCSV), 'sweet potato virus 2' (SPV2), both viruses (SPCSV + SPVY), and of non-inoculated plants (healthy). Vertical bars represent standard errors of means of 8 plants for each treatment. Treatments were compared by single-factor ANOVA and means separated at $P \leq 0.05$ level.

also contained a characteristic NIa protease cleavage site (VYHQ/S). In close proximity to this cleavage site, the CP amino terminus carries the amino acid triplet DAG that is involved in aphid transmission of poty-viruses (Atreya *et al.*, 1995). The non-persistent transmission of SPV2 was confirmed experimentally by *Myzus perscae*.

BLAST search analysis of the SPV2 sequences gave highest scores with potyvirus isolates from sweetpotato. Based on the phylogenetic tree of the CP amino acid sequences (Figure 2A), the closest relatives of SPV2 appear to be SPV-Zw (Chavi *et al.*, 1997) and SPVG, which share CP amino acid sequence similarities with SPV2 of 80 % and 77 %, respectively (Table 2). Much lower CP

Table 1: Distribution and titres of SPV2 and SPCSV in *I. setosa* plants infected with SPV2 or SPCSV alone and in dually infected plants.

Leaf stage	DAS-ELISA readings ¹ for SPV2 in plants infected with		TAS-ELISA readings for SPCSV in plants infected with	
	SPV2 alone	SPV2 + SPCSV	SPCSV only	SPV2 + SPSV
Bottom	0.618	0.915	0.034	0.154
Intermediate	0.175	0.784	1.103	1.454
Top	0.040	0.767	0.266	0.401

¹Absorbance readings were measured at A₄₀₅. Data are means from three randomly selected plants.



Figure 2: Neighbour-joining relationship dendrograms of the coat protein (CP) core amino acid (A) and 3' UTR nucleotide sequences (B) of SPV2 and other sweet potato infecting poty-viruses, with the CP and 3' UTR sequences of PVY^N used as outgroup sequences. Vertical branch lengths are arbitrary, horizontal branch lengths are proportional to percent sequence differences, and numbers at each node indicate bootstrap scores higher than 50%. Virus (isolate) designations and accession numbers are SPV2 (AY232437), SPV-Zw (AF016366), SPVG (X76744), SPFMV-RC (S43450), -C (S43451), -S (D86371), -O (D16664), -6 (U96625), SwPLV (X84011), SPMSV (U61228), and PVY^N (AY166867).

Table 2: Percent coat protein amino acid sequence (lower diagonal) and 3'UTR nucleotide sequence identities (upper diagonal) following pairwise alignments of SPV2 and other potyviruses infecting sweet potato.

Virus	SPV2	SPV-Zw	SPVG	SPFMV isolate					SwPLV	SPMSV
				-6	-C	-RC	-S	-O		
SPV2		82.1	82.2	56.3	79.0	78.6	77.8	77.4	55.5	44.0
SPV-Zw	80.0		79.5	55.7	77.9	77.5	75.8	75.3	45.6	43.5
SPVG	77.3	75.0		47.5	75.3	75.3	75.1	74.7	51.8	38.8
SPFMV-6	74.4	71.3	72.3		71.0	70.1	72.1	73.1	44.1	49.5
SPFMV-C	74.7	72.4	72.4	92.7		97.7	99.1	98.6	50.3	45.6
SPFMV-RC	76.4	73.3	74.4	81.2	84.7		98.2	96.4	50.8	45.6
SPFMV-S	76.3	73.3	74.1	82.3	84.4	99.0		97.8	50.3	46.1
SPFMV-O	76.4	72.3	74.5	80.8	83.1	95.6	95.2		51.3	45.2
SwPLV	62.3	61.6	61.6	63.1	62.2	64.1	64.1	62.3		46.1
SPMSV	57.7	57.4	60.4	59.8	60.9	58.7	59.3	60.2	58.8	

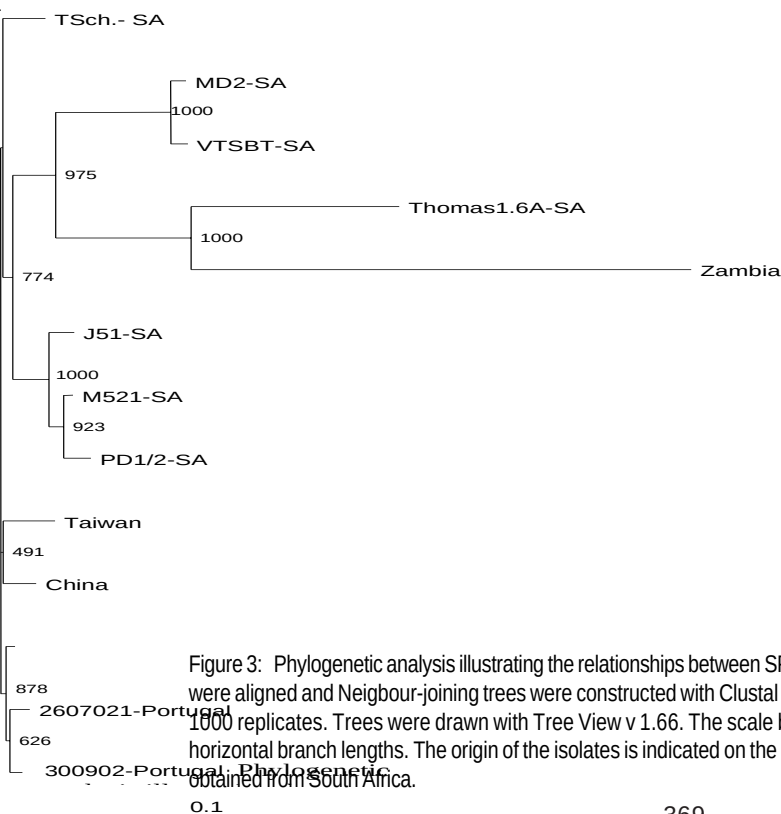


Figure 3: Phylogenetic analysis illustrating the relationships between SPV2 isolates. Coat protein nucleotide sequences were aligned and Neighbour-joining trees were constructed with Clustal X v1.83. Bootstrap values were calculated from 1000 replicates. Trees were drawn with Tree View v 1.66. The scale bar represents a genetic distance of 0.1 for the horizontal branch lengths. The origin of the isolates is indicated on the branches. Isolate names ending with -SA were obtained from South Africa.

amino acid sequence similarities were observed between SPV2 and SPFMV (~75%), SwPLV (69%), and SPMSV (63%) (Table 2). Phylogenetic analysis (Figure 2B) and pairwise alignments (Table 2) of 3' UTR sequences of sweetpotato potyviruses also supported the notion that SPV2 is more closely related to SPV-Zw (82%) and SPVG (82%) than to SPFMV (78%), SwPLV (56%) and SPMSV (44% only). The 3' UTR size (without poly (A) tail) of SPV2 (216 nt) was very similar to that of SPV-Zw (215 nt), SPVG (221 nt), and SPFMV (222 nt), whereas it differed considerably from that of SPMSV (248 nt) and SwPLV (196 nt).

To determine the relationship between geographically diverse isolates of SPV2 the nucleotide (nt) sequences of the CP genes of twelve isolates from different geographical regions were obtained. The comparison of the CP encoding nt sequences gave identities ranging from 81-100%, whereas the CP aa similarities ranged from 86 to 100% (data not shown). Thomas 1.6A and Zambia consistently took a position divergent from all the other isolates. Apart from Thomas 1.6A, all isolates from South Africa were closely related (94 - 100%) to one another and to isolates from China, Portugal and the type isolate from Taiwan (Figure 3).

Discussion

In synergy studies using *I. setosa* as a model host, plants co-infected with SPV2 and SPCSV showed very severe and conspicuous symptoms on all leaves and strikingly enhanced levels in SPV2 accumulation and distribution as compared to singly infected plants (Figure 1; Table 1). Since the symptoms observed on the dually infected plants were typical of potyviruses and the titre and distribution of SPV2 but not those of SPCSV were dramatically enhanced, it is conceivable that the greater damage observed for the dually infected plants was due to SPV2. These observations and conclusions are in agreement with those made for SPFMV,

another sweetpotato potyvirus that caused more severe symptoms and accumulated several-fold in sweetpotato and *I. setosa* plants co-infected with SPCSV (Gibson *et al.*, 1998; Karyeija *et al.*, 2000). It was suggested that the crinivirus suppresses the resistance mechanism of sweetpotato to the potyvirus leading to its accumulation (Karyeija *et al.*, 2000). In this type of synergistic interaction, SPCSV-encoded factors might be responsible for the suppression of the host's defense mechanism thereby permitting an enhanced multiplication of potyviruses, such as SPV2 and SPFMV.

In order to further characterize SPV2, an incompletely described potyvirus isolate from sweetpotato in Taiwan, some of its molecular properties were determined. The taxonomic assignment of SPV2 to the genus Potyvirus was supported by the sequence analysis of the 3'-terminal portion of SPV2 RNA. Based on one of the major demarcation criteria for potyvirus species ("CP amino acid identity of < about 80%" Berger *et al.*, 2000), SPV2 is clearly different from SPMSV (58%), SwPLV (62%), and SPFMV (~75%) (Table 3). In view of the notion that distinct potyvirus species have 3'-UTR sequence identities of < 80% (Frenkel *et al.*, 1989; Shukla *et al.*, 1994), it should also be pointed out that the 3'-UTR nucleotide sequence identities between SPV2 and the other potyvirus species SPMSV (38%), SwPLV (49%), and SPFMV (77%) did not exceed 80% (Table 2).

The CP aa sequence similarities among the SPV2 isolates sequenced ranged from 86 to 100%, which is within the suggested thresholds of distinct viruses (Frenkel *et al.*, 1992, 1989; Shukla *et al.*, 1994). The isolates from Zambia and Thomas 1.6A each represent distinct strains of SPV2 whereas the other 12 isolates belong to a third strain of closely related isolates. It is unknown how widespread strains similar to Zambia and Thomas 1.6A or other divergent strains are. More work needs to be done to get a better understanding of the range of variability in SPV2, and to determine if certain deviant

strains escape serological detection. In conclusion, based on the properties determined in this study, SPV2 is a distinct member of the genus *Potyvirus*. We propose that it be named Sweetpotato virus Y.

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Genotype by environment interaction (GXE) for native cassava (*Manihot esculenta* Crantz) starch quality and its use in the commercial sector

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Abstract. Cassava (*Manihot esculenta* Crantz) is the second most important staple food crop in Sub-Saharan Africa providing an average of 285 calories per person per day. Cassava is an important food and cash crop, and it is increasingly becoming important industrial crop in Malawi. Various cassava intermediate products are used but industries hesitate to use cassava starch because powder sold by some suppliers in the name of cassava starch failed. This study therefore was initiated to look into native cassava starch qualities from different Malawi cassava genotypes, determine the appropriate stability parameter to deal with genotype by environment interaction (GxE) for starch quality traits, and also find out the possibility of use of cassava starch by the main industries in Malawi. Trials were conducted in Malawi in 2000/01 season. Apart from starch quality parameters, root dry matter and starch extraction evaluation were also included. Various stability measures were used to deal with the problem of genotype by environment interaction. Feasibility of use of cassava starch in Malawian industries was also conducted. The results show that all the cassava genotypes produced starch with no protein just like the one used in the pharmaceutical industry. The moisture and ash content were much lower than the recommended allowable maximum. The pH for cassava starch was within the recommended

range. Additive main effects and multiplicative interaction (AMMI) was strongly correlated with other stability parameters like Wicovalence and stability variance—no covariate. AMMI is therefore recommended for use in the stability analysis of starch quality parameters since it provides additional information on appropriate environments for unstable genotypes. This study suggests that genotype has a greater influence on root dry matter than the environment. This study showed that native cassava starch can be used in the pharmaceutical, battery and packaging material making and textile industries in Malawi, however strict quality control for cassava starch is required.

Introduction

Cassava (*Manihot esculenta* Crantz) is the second most important staple food crop in Sub-Saharan Africa providing an average of 285 calories per person per day (FAO, 2000). The most important feature of cassava is its adaptability to a wide variety of ecological and agronomic conditions. In contrast to other staples, it grows well under marginal conditions (Silvestre, 1989). Apart from this ecological versatility, cassava also displays certain characteristics that makes it adaptable to a variety of socio-economic conditions (De Vries, 1978; Hallack, 2001; IITA, 2001; Moyo *et al.*, 1998; Silvestre, 1989).

Cassava starch is used directly in different ways or as a raw material for further processing (FAO, 2000) of various products such as food, textile, paper, adhesives, chemicals, glucose, soap, detergent, laundry, ethanol, cosmetic powders, sausage making, pharmaceuticals and insecticides. The unique properties of cassava starch suggest its use for speciality markets such as baby foods and non-allergenic products. Industries that use starch in Malawi have a negative attitude towards the use of cassava starch, because some industries have been buying local products in the name of cassava starch which were not as efficient as the corn starch which is normally used (Fungulani and Maseko 2001; Itaye 2001). There was therefore a need to determine the quality of cassava starch from different genotypes that are grown in Malawi. In addition, industries were to be supplied with proper native cassava starch so that they test its effectiveness in their production process.

Dry matter content is closely related to starch content in cassava. This makes dry matter an important trait to cassava producers since it is a crop grown largely for its carbohydrate content. Dry matter varies very widely in cassava over years and environments (CIAT, 1995).

Genotype by environment interaction (GxE) is an important issue facing plant breeders and agronomists in Malawi with a wide range of agroecologies and variable climate. Breeders constantly strive to develop improved genotypes that are superior in a number of agronomic and quality traits, over a relatively wide range of environmental conditions. Plant breeders generally agree on the importance of high and stable yield, but there is less agreement on the most appropriate definition of stability and on methods to measure and improve yield stability. These GxE interactions can be partly understood as a result of differential reactions to environmental stresses, such as drought, diseases and other factors (Becker and Léon, 1988). The function of experimental design and statistical analyses of multilocation trials is thus to eliminate and discard as much of

unexplainable noise as possible (Crossa *et al.*, 1990).

Industries in Malawi have had a negative attitude towards the use of cassava starch. This has been so because some industries bought local products in the name of cassava starch which were either not as efficient as the corn starch which is normally used or in some industries led to a total failure (Fungulani and Maseko, 2001; Itaye, 2001). This scenario has been worrisome as far as cassava commercialisation is concerned. Cassava production is increasing, hence there is need to find markets for cassava so that it should not only be taken as a food security crop but also a cash crop. This is because most of the cassava products are multipurpose, thus, used as food and also have commercial value. This can only be achieved if cassava products can be used in various industries especially starch which has various uses in various specialised industries.

The objectives of this study therefore were: (i) to evaluate the elite Malawi cassava genotypes for dry matter content; (ii) to evaluate the native starch extraction rate for elite Malawi cassava genotypes; (iii) to evaluate the elite Malawi cassava genotypes for quality of the native starch extracted from them; (iv) to assess GxE interaction of the starch quality traits included in this study, (v) To determine the appropriate stability measure for dealing with GxE interactions, and (vi) to assess the possibility of use of native cassava starch in the major industries in Malawi.

Materials and Methods

Five recommended varieties, six locally bred clones, and nine introduced clones were evaluated at Chitedze and Makoka research stations in 2000/01 season. A randomised complete block design was used with four replicates. The plot sizes were four ridges, each with 12 plants (gross) and a net of two inner ridges each with 10 middle plants. The plants were planted on ridges at a spacing of 0.9 m by 0.9 m apart. The lengths of the stakes were 25 cm and they were planted in a slanting position at about 45°.

About five undamaged roots were randomly selected for use in determination of dry matter. Medial sections of the tubers were shredded into thin slices, mixed thoroughly and a duplicate of 200 g samples for each genotype were weighed and put in containers. The samples were dried at 65°C for 72 hours, and weighed immediately after removal from the oven. These steps were carried out within 24 hours after harvest to avoid post harvest changes through physiological deterioration or moisture loss of the root. Dry matter content was calculated based on the weight loss.

Native starch extraction was done using a the method of Numfor and Walter (1996). Ash content of starch was determined using a the method of CRA standard analytical method (1999), ISO (1997a) and ISI (2002a). pH of starch was determined using the method of ISI (2002c) which is applicable to native and modified starch, glucose syrups and hydrolysates. Moisture content for starch was determined using the method of ISO (1976) which is applicable to starch, dextrose - anhydrous and monohydrate - and total sugar.

Protein content of starch was analysed using an automatic Protein/Nitrogen Determinator LECO FP-528. Duplicate starch samples of about 3 g were dried in an oven at 105°C for 72 hours, and then cooled in a desiccator for 1 hour. Samples of 0.30 g were weighed immediately after removal from the desiccator and then loaded into the protein analyser.

Whiteness of starch was measured using a HunterLab ColorFlex 45°/0° at the Southern African Grain Laboratory, in South Africa. Colour values measured using the ColorFlex are relative to the absolute value of a perfect reflecting diffuser as measured under the same geometric conditions (ASTM Method E 308). The Hunter scale (L) measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it.

Industrial use of cassava products was reviewed by Fungulani and Maseko (2001),

Itaye (2001) and Mataya (2001). The review also included previous visits to the industries by various stakeholders, and previous studies that were done by different players like the University of Malawi in collaboration with Packaging Industries Malawi Limited (PIM). In addition, industrial uses of native cassava starch was sought from various industries in Malawi by visiting them and holding discussions with the relevant authorities and departments. Trials were also set up with various industries using cassava starch, that is: David Whitehead and Sons in the textile industry, Nzeru radio company in the battery making industry, and Malawi Pharmacies Limited (MPL) in the pharmaceutical industry. Cassava starch, which was produced at Chitedze research station, was used for all the trials in the different industries.

Data analysis. An analysis of variance was performed on all measured characteristics of the individual trials. Thereafter combined analyses of variance were performed on the pooled data of both trials for Chitedze and Makoka. The GxE interactions for the traits that were significant were managed using different stability methods. All computations were performed with Agrobases 20 (Agrobases, 2000). Stability variance for each genotype across environments was determined (Shukla, 1972). The data set was also analysed according to the procedure recommended by Lin and Binn (1988). Wricke's ecovalence (1962) was also done. Genotypes with low ecovalence have smaller fluctuations from the mean across different environments and are therefore more stable. AMMI combines analysis of variance for genotype and environment main effects with principal components analysis of the GxE interaction into a unified approach, and is especially useful in analysing multi-location trials (Gauch, 1988; Zobel, 1988). To statistically compare the four stability analysis procedures, Spearman's coefficient of rank correlation was used (Steel and Torrie, 1980), where it applies to data in the form of ranks.

Results and Discussions

Dry matter content in cassava roots. There were significant differences among the genotypes at Makoka, and the highest root dry matter content was for 30786, Silira, Mbundumali and Mkondezi (Table 1), and their dry matter were significantly higher than for CH92/112 and 83350. There were no significant differences between the genotypes at Chitedze. Mbundumali and Silira had the highest dry matter while CH92/112 had the lowest dry matter at both locations (Table 1). There were significant differences in the main effects for root dry matter content for locations, and for the genotypes, but there was no significant GxE interaction (Tables 2).

Although the locations gave highly significant differences in root dry matter content in cassava its contribution to the variation was only 7.94 % while genotypes contributed 36 %. The low contribution of variation of the locations, coupled with insignificant GxE interaction, and the main effects for the replicates (Table 2) suggests that dry matter content is not as much influenced by environment as by genetic differences. These results agree with other studies of Pérez *et al.* (2001) that found that dry matter content in roots of cassava is likely to be controlled by one or a few major genes. However, this differs with the suggestions of CIAT (1995) that the performance of genotypes on root dry matter content

Table 1: Mean root dry matter and starch extraction for 20 Malawi cassava genotypes evaluated at Chitedze and Makoka in 2000/01

Genotype	Root dry matter			Starch extraction rate		
	Chitedze	Makoka	Mean	Chitedze	Makoka	Mean
Silira	46.10	46.85	46.48	30.68	42.88	36.78
Sauti	39.05	41.25	40.15	43.43	42.49	42.96
CH92/082	42.75	41.53	42.14	39.04	47.35	43.19
TMS4(2)1425	39.23	43.03	41.13	41.27	45.68	43.47
CH92/112	37.63	38.85	38.24	27.35	41.33	34.34
CH92/105	39.75	42.58	41.16	34.87	36.24	35.56
LCN8010	40.40	43.60	42.00	34.01	46.68	40.35
30786	40.55	47.68	44.11	32.54	44.29	38.42
83350	40.95	38.15	39.55	34.72	52.05	43.38
TME1	41.30	45.35	43.33	27.62	43.82	35.72
81/00015	40.05	43.75	41.90	39.33	47.30	43.31
CH92/108	39.83	44.73	42.28	34.06	33.18	33.62
MK95/054	39.00	44.90	41.95	29.26	43.72	36.49
Mbundumali	46.68	46.48	46.58	33.36	40.95	37.16
Gomani	43.10	43.05	43.08	34.11	45.86	39.99
Mkondezi	39.65	46.28	42.96	26.25	41.69	33.97
TMS60121	43.58	43.15	43.36	33.29	45.40	39.34
TMS84563	42.88	41.80	42.34	29.85	45.43	37.64
Maunjili	44.65	43.68	44.16	37.71	40.11	38.91
TMS60142A	44.68	45.40	45.54	38.39	42.24	40.31
Mean	41.44	43.69	42.57	34.06	43.43	38.74
CV (%)	8.73	4.83	6.97	15.16	10.51	12.58
LSD for G	NS	7.54	6.97	NS	NS	NS
LSD for L	-	-	2.21	-	-	3.62

CV=coefficient of variation; SED=standard error deviation; Sign.=probability level of significance; G=genotype; L=location

Table 2: Analysis of variance for root dry matter and starch extraction rate

Source of Variation	df	Dry matter (%)		Starch extraction rate (%)	
		Sum of Squares (SS)	Contribution to SS (%)	Sum of Squares (SS)	Contribution to SS (%)
Total	79	970	-	4470	-
Location (L)	1	77 **	7.94	1759 ***	39.35
Rep (location)	2	56	5.77	314	7.02
Genotype (G)	19	344 *	35.46	839	18.77
G x L	19	158	16.29	656	14.68
Error	38	335	34.54	902	20.18

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

strongly depend on edaphic-climatic and agronomic conditions.

Starch extraction from cassava roots. There were no significant differences in starch extraction among the genotypes at both locations (Table 1), but there were highly significant differences between the locations, with Makoka having a higher starch extraction rate. This agrees with observations made that the cassava roots at Makoka were very mealy as compared to the same genotypes at Chitedze. These differences could be attributed to the differences in the distribution of the rainfall at these two locations. Extended dry weather might have forced the plants at Chitedze to use their food reserves by breaking down some of the starch into sugars for survival during the dry season. The locations made the largest contribution to variation (Table 2). This suggests that one needs to consider where cassava should be grown and when should it be harvested to maximise starch extraction from the storage roots. There was no significant GxE interaction (Tables 2) in starch extraction, therefore the performance of the cassava genotypes for starch extractions were not influenced by locality.

Protein content in cassava starch. All the cassava genotypes produced starch without any protein just like the corn starch used in various industries. The lower the protein

content, the higher the quality of that starch. Different industries have set different maximum protein content in starch but all are lower than 1.0 %.

Whiteness of starch. There were significant differences among the genotypes for Chitedze and Makoka. Most of the cassava genotypes were statistically similar to cornstarch used by the industries (Table 3). There were significant differences in the main effects between the locations, and among the genotypes (Table 3), but the interaction of genotype by location was not significant. The genotype contributed the most to variation (72.40 %). Although the GxE interaction was not significant, it still contributed a much higher amount of variation than location (Table 4). The whitest starch was the cornstarch, but there were no significant differences with the starch from Gomani and Sauti (Table 3). Generally, Chitedze produced whiter starch than Makoka. The colour of starch is very important where the colour of the final product matters. This study therefore showed that cassava can be grown anywhere and any genotype can be used to produce white starch acceptable to all industries.

pH of starch. There were highly significant differences among the genotypes at both locations. The genotypes that produced starch with the highest pH at Chitedze were CH92/108, Silira, CH92/082 and TME1, while

Table 3: Whiteness, pH, moisture content and ash content for starch evaluated in 2000/01 season.

Genotype	Whiteness of starch (L)				pH of starch				Starch moisture content (%)				Starch ash content (%)			
	Chitedze	Makoka	Mean		Chitedze	Makoka	Mean		Chitedze	Makoka	Mean		Chitedze	Makoka	Mean	
Silira	94.75	94.75	94.75		5.5	5.5	5.5		13.10	14.20	13.65		0.13	0.11	0.12	
Sauti	96.02	96.02	96.02		5.2	5.1	5.2		12.60	13.70	13.15		0.09	0.11	0.10	
CH92/082	94.94	94.94	94.94		5.4	5.5	5.5		12.20	14.30	13.25		0.09	0.15	0.12	
TMS4(2)1425	95.36	95.36	95.36		5.0	5.3	5.2		11.20	14.20	12.70		0.22	0.13	0.17	
CH92/112	93.49	93.49	93.49		5.1	5.5	5.3		10.30	13.70	12.00		0.15	0.13	0.14	
CH92/105	94.56	94.56	94.56		4.8	5.5	5.2		11.40	12.30	11.85		0.13	0.13	0.13	
LCN8010	94.63	94.63	94.63		5.1	5.7	5.4		11.80	13.40	12.60		0.20	0.14	0.15	
30786	94.94	94.94	94.94		5.2	5.6	5.4		11.80	13.50	12.45		0.10	0.16	0.13	
83350	96.11	96.11	96.11		5.2	5.1	5.2		12.50	12.90	12.70		0.25	0.15	0.20	
TME1	94.51	94.51	94.51		5.3	5.3	5.3		11.60	13.70	12.65		0.20	0.11	0.15	
81/00015	94.84	94.84	94.84		5.1	5.6	5.4		11.80	14.00	12.90		0.13	0.11	0.12	
CH92/108	95.42	95.42	95.42		5.5	6.2	5.9		12.20	14.00	13.10		0.22	0.13	0.17	
MK95/054	93.77	93.77	93.77		5.0	6.0	5.5		12.70	12.90	12.80		0.11	0.16	0.13	
Mbundumali	96.28	96.28	96.28		4.8	5.7	5.3		12.60	13.10	12.85		0.12	0.19	0.15	
Gomani	96.33	96.33	96.33		5.1	5.9	5.5		12.80	12.60	12.70		0.09	0.19	0.14	
Mkondezi	94.81	94.81	94.81		4.9	5.7	5.3		12.60	13.20	12.90		0.12	0.09	0.11	
TMS60121	95.38	95.38	95.38		5.0	5.8	5.4		12.00	13.70	12.85		0.18	0.09	0.13	
TMS84563	95.22	95.22	95.22		4.7	5.8	5.3		12.10	12.00	12.05		0.12	0.13	0.12	
Maunjili	95.48	95.48	95.48		4.9	5.1	5.0		12.80	13.90	13.35		0.13	0.10	0.11	
TMS60142A	95.64	95.64	95.64		4.9	5.7	5.3		14.00	12.70	13.35		0.14	0.09	0.11	
Nzeru corn starch	95.20	95.20	95.20		4.7	4.7	4.7		11.20	11.20	11.20		0.15	0.14	0.14	
PIM corn starch	96.46	96.46	96.46		5.1	5.0	5.0		11.80	11.80	11.80		0.18	0.13	0.15	
MPL corn starch	97.28	97.28	97.28		4.1	4.1	4.1		9.90	9.90	9.90		0.11	0.14	0.12	
Corn flour	94.20	94.20	94.20		3.4	3.4	3.4		10.60	10.60	10.60		0.86	0.70	0.78	
Mean	95.33	95.33	95.33		5.0	5.4	5.2		11.97	12.98	12.47		0.17	0.15	0.16	
CV (%)	0.83	0.83	0.83		0.19	0.15	0.17		5.96	4.54	5.25		11.40	9.36	12.04	
LSD for G	1.97	1.97	1.97		0.02	0.02	0.02		1.78	1.47	1.12		0.05	0.04	0.03	
LSD for L	.	.	.		.	.	0.01		.	.	0.32		.	.	0.01	

G=genotype; L=location; MPL=Malawi pharmacies limited; PIM= Packaging industries Malawi limited; Nzeru=Nzeru radio company.

Table 4: Analysis of variance for whiteness, pH, moisture and ash content for 20 Malawi cassava genotypes evaluated at Chitedze and Makoka in 2000/01 season.

Source of Variation	df	Whiteness (L)		pH of starch		Moisture content (%)		Ash content (%)	
		Sum of Squares (SS)	Contribution to SS (%)	Sum of Squares (SS)	Contribution to SS (%)	Sum of Squares (SS)	Contribution to SS (%)	Sum of Squares (SS)	Contribution to SS (%)
Total	95	120.7	-	30.227	-	147.85	-	1.752	-
Location (L)	1	2.6 *	2.15	4.084 ***	13.51	24.60 ***	16.64	0.011 ***	0.61
Rep (location)	2	7.5	6.21	0.001	0.00	0.52	0.35	0.014	0.79
Genotype (G)	23	72.4 ***	58.88	22.615 ***	74.82	73.32 ***	49.59	1.617 ***	92.29
G x L	23	12.5	10.36	3.523 ***	11.66	29.71 ***	20.10	0.093 ***	5.30
Error	46	25.8	21.30	0.004	0.01	19.70	13.32	0.018	1.01

*** $p \leq 0.001$ * $p \leq 0.05$.

the lowest pH was detected in cornstarch (Table 3). At Makoka CH92/108, Silira Gomani and MK95/054 had the highest pH, while the cornstarch had the lowest pH. The pH for native starch ranged from 4.7 to 5.8 at both sites, which was within the recommended industry range of 4.5 and 7.0. There were highly significant differences in the main effects (locations and genotypes) and their interaction. The genotypes contributed 74.82 % of variation (Tables 4). CH92/108, Silira MK95/054, Gomani and CH92/082 had a high pH. Makoka gave a higher mean pH value of 5.4 for starch than Chitedze (pH 5.0, Table 3), though both sites had pH values that were within the recommended range of between 4.5 and 7.0 (African Products (Pty) Limited, 2001; National starch and chemical company, 2002).

Since the GxE interaction was highly significant for starch pH, it was difficult to single out superior genotypes using main effect means only, therefore stability analyses was done. According to the cultivar performance measure (P_i) 83350, CH92/108, TMS4(2)1425, LCN8010, TME1 and CH92/112 were the most stable (Table 5). According to Wi-ecovalence, the most stable genotypes were Silira, CH92/112, CH92/105, Maunjili, Mkondezi, TMS84563 and TMS60142A. In Table 5, Shukla's stability variance (σ^2_i) values, as well as the ranking order of the genotypes' stability are given. According to the stability variance – no covariate, Mkondezi, Maunjili Silira, CH92/112, CH92/105 TMS60121, TMS60142A and Sauti were stable. AMMI IPCA scores showed that the most stable genotypes were 81/00015, 30786, CH92/112, LCN6010 and CH92/108 (Table 5).

The overall ranking of the genotypes for stability using the four stability parameters showed that CH92/112, 81/00015, LCN8010, CH92/105, CH92/108 and Silira were stable (Table 5). Spearman's coefficient of rank correlation was determined for traits with significant GxE interaction (Table 6). The results show that Wi-ecovalence was significantly and positively correlated to stability variance – no covariate. The other stability parameters were not correlated. The

Table 5: Summary of stability statistics for pH in starch from 20 Malawi cassava genotypes tested at Chitedze and Makoka in 2000/01 season.

Genotype	Cultivar superiority		Wi-Ecovalence		Stability variance-no covariate		AMMI		Overall Rank
	Pi Stat.	GxE Rank	Wi Stat.	GxE Rank	δ^2_i Stat.	Rank	IPCA scores	Rank	
Silira	0.0051	9	0.0000	1	-0.0001	2	-0.3806	13	5
Sauti	0.0082	17	0.0013	6	0.0008	5	-0.4566	16	13
CH92/082	0.0068	16	0.0058	10	0.0042	9	-0.3162	11	14
TMS(2)1425	0.0011	2	0.0058	10	0.0042	9	-0.1601	6	6
CH92/112	0.0035	5	0.0000	1	-0.0001	2	-0.0821	3	1
CH92/105	0.0044	8	0.0003	3	0.0001	2	0.1617	7	3
LCN8010	0.0013	3	0.0019	7	0.0013	6	0.0954	4	3
30786	0.0058	13	0.0058	10	0.0042	9	-0.0743	2	9
83350	0.0004	1	0.0070	11	0.0051	10	-0.4508	15	11
TME1	0.0022	4	0.0058	10	0.0042	9	-0.3806	13	10
81/00015	0.0052	10	0.0000	1	-0.0001	2	0.0096	1	2
CH92/108	0.0011	2	0.0051	9	0.0036	8	0.1461	5	4
MK95/054	0.0053	11	0.0047	8	0.0034	7	0.3938	14	12
Mbundumali	0.0042	7	0.0070	11	0.0051	10	0.3216	12	12
Gomani	0.0064	14	0.0129	12	0.0094	11	0.2300	9	14
Mkondezi	0.0066	15	0.0002	2	0.0000	1	0.2378	10	7
TMS60121	0.0037	6	0.0058	10	0.0042	9	0.2300	9	9
TMS84563	0.0052	10	0.0008	4	0.0005	3	0.4660	17	9
Maunjili	0.0058	13	0.0002	2	0.0000	1	-0.2284	8	4
TMS60142A	0.0055	12	0.0010	5	0.0006	4	0.2378	10	8

Table 6: Spearman's coefficients of rank correlation for four GxE stability analysis procedures conducted for (1) pH, (2) moisture content and (3) ash content of starch from 20 cassava genotypes evaluated over two locations in Malawi.

Stability Parameter	Cultivar superiority measure (Pi)	Wi-Ecovalence	Stability variance – no covariate	AMMI
Wi-Ecovalence	(1) -0.2275 (2) 0.4999* (3) 0.3125			
Stability variance – no covariate	(1) -0.2700 (2) 0.3586 (3) 0.1313	(1) 0.9866*** (2) 0.7892*** (3) 0.8804***		
AMMI	(1) 0.1975 (2) 0.4118 (3) -0.2004	(1) 0.1640 (2) 0.7995*** (3) 0.1603	(1) 0.1149 (2) 0.996** (3) 0.0664	
Overall Rank	(1) 0.3990 (2) 0.6477** (3) 0.5495*	(1) 0.6795** (2) 0.9101*** (3) 0.8396***	(1) 0.6469** (2) 0.9050*** (3) 0.7214***	(1) 0.6600** (2) 0.9176*** (3) 0.3825

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.

overall rank was not correlated to cultivar superiority measure, but there were significant correlations with Wi-ecovalence, stability variance – no covariate and AMMI. The stability parameter that was closest to the overall rank was Wi-ecovalence, followed by AMMI and the stability variance – no covariate, came third (Table 6).

The genotypes that were stable suggest that they were universal, thus their pH was not dependent on environment while those that were unstable were specifically adapted to certain environments. The AMMI analysis showed that MK95/054 and TMS84563 were unstable and were best suited to Makoka, and Sauti and 83350 were also unstable and were best suited to Chitedze. Any one of Wi-ecovalence, stability variance or AMMI can be used for stability analysis, but AMMI is recommended since it provides additional information on the allocation of unstable genotypes into their appropriate environments.

Moisture content in starch. There were highly significant differences among the genotypes at Chitedze, and Makoka (Table 3). The cornstarch had the lowest moisture content. The range of moisture content at both sites ranged from 10.3 to 14.3 %, which was below the recommended maximum of 15 %. There were highly significant differences in the main effects (locations and genotypes) and for their interaction. The locations contributed 16.64 % to the variation, the genotypes 49.59 %, and GxE contributed 20.10 % (Table 4). Silira, Maunjili, TMS60142A, CH92/082, Sauti and CH92/108 had high mean moisture content (Table 3). Cornstarch from Malawi Pharmacies Limited (MPL) gave the lowest moisture content. The mean moisture content was below the industry recommended maximum of 15%. Makoka had a higher moisture content of 12.47 % than Chitedze (11.97 %, Table 3), but both sites had a starch moisture content that was below the recommended maximum values of 14-15 % (National starch and chemical company, 2002). According to cultivar performance measure (P_i), Silira,

Maunjili, Sauti, TMS60142A and Mkondezi were the most stable (Table 7). According to Wi-ecovalence, the most stable genotypes were Silira, Sauti, CH92/105, LCN8010, TMS60121 and TMS60142A. According to the stability variance – no covariate, the cassava genotypes which were stable were Maunjili, Silira, CH92/105, LCN8010, TMS60121, CH92/108 and Sauti. Using AMMI IPCA scores, the most stable genotypes were Silira, Sauti, Maunjili, CH92/105, LCN6010, TMS60121 and CH92/108 (Table 7). Using all four stability parameters, the most stable genotypes were Silira, Maunjili, Sauti, LCN8010, CH92/105 and TMS60121. The Spearman's coefficient of rank correlation showed that Wi-ecovalence was significantly and positively correlated to stability variance – no covariate, and AMMI. AMMI was also significantly and positively correlated with stability variance – no covariate. Cultivar superiority measure was only correlated to Wi-ecovalence at 5 % alpha level (Table 6).

The overall rank was highly significantly correlated to all the stability parameters hence any one of them could be used to test the stability of the genotypes for moisture content (Table 6) but AMMI is recommended since it also allocates unstable genotypes to their respective areas of their best performance. The AMMI analysis showed that TMS4(2)1425 and CH92/112 were best suited to Makoka, while TMS60142A, TMS84563 and Gomani were best suited to Chitedze. Therefore for moisture content of starch any one of the four stability parameters can be used.

Ash content in starch. There were highly significant differences among the genotypes at both locations (Table 3). The range of ash content at both sites ranged from 0.09 to 0.25 % that was much lower than the recommended maximum of 0.5 % for the industry. There were highly significant differences in the main effects (locations and genotypes) and their interaction. Genotypes contributed 92.29 % of the variation (Table 4). Genotypes 83350,

Table 7: Summary of stability statistics for moisture content of starch from 20 Malawi cassava genotypes, tested at Chitedze and Makoka in 2000/01 season.

Genotype	Cultivar superiority		Wi-Ecovalence		Stability variance- no Covariate		AMMI		Overall Rank
	Pi GxE Stat.	Rank	Wi GxE Stat.	Rank	d ² _i GxE Stat.	Rank	IPCA scores	Rank	
Silira	0.2050	1	0.0066	1	-0.0385	2	0.0515	1	1
Sauti	0.5800	3	0.0066	1	-0.0385	2	0.0515	1	3
CH92/082	0.8100	6	0.3916	11	0.5319	9	-0.3966	9	8
TMS4(2)1425	1.9625	16	1.5931	16	2.3119	14	-0.8000	14	16
CH92/112	3.5125	19	2.3871	10	3.4881	15	-0.9793	15	15
CH92/105	2.6900	18	0.0496	2	0.0252	1	0.1412	2	5
LCN8010	1.4125	13	0.0741	3	0.0615	3	-0.1725	3	4
30786	1.8500	15	0.3916	11	0.5319	9	-0.3966	9	12
83350	1.0525	10	0.3321	9	0.4437	8	0.3653	8	9
TME1	1.5300	14	0.3916	11	0.5319	9	-0.3966	9	11
81/00015	1.2325	12	0.4851	12	0.6704	10	-0.4415	10	12
CH92/108	0.8325	7	0.1711	6	0.2052	5	-0.2622	5	5
MK95/054	0.9125	9	0.5151	13	0.7148	11	0.4549	11	12
Mbundumali	0.8500	8	0.2556	8	0.3304	7	0.3204	7	7
Gomani	1.0825	10	1.0011	15	1.4348	13	0.6342	13	13
Mkondezi	0.7925	5	0.1891	7	0.2319	6	0.2756	6	6
TMS60121	1.0900	11	0.1176	4	0.1259	4	-0.2174	4	5
TMS84563	2.2250	17	0.8646	14	1.2326	12	0.5894	12	14
Maunjili	0.4000	2	0.0066	1	-0.0385	2	0.0515	1	2
TMS60142A	0.6400	4	3.1626	5	4.6370	16	1.1272	16	10

CH92/108, TMS4(2)1425, TME1 and Mbundumali had the highest ash content (Table 3), while MPL cornstarch, 81/00015, TMS60142A, Maunjili, Mkondezi and Sauti had the lowest. The ash content of starch from cassava genotypes was not different from the cornstarch obtained from various industries.

Chitedze gave higher mean ash content of 0.17 % for starch than Makoka (0.15 %, Table 3), but both sites gave starch ash content which was lower than the recommended maximum of 0.5 % (National starch and chemical company, 2002).

According to the cultivar performance measure (P_i) CH92/108, Gomani, MK95/054, LCN8010 and TMS60121 were the most stable (Table 7). According to Wi-ecovalence, the most stable genotypes were 81/00015, CH92/112, 30786, LCN8010 and CH92/108. According to the stability variance – no covariate, the cassava genotypes which were

stable were 30786, CH92/112, 81/00015, LCN8010 and CH92/108. Using AMMI IPCA scores, the most stable genotypes were Silira, 81/00015, CH92/112, Mkondezi, Maunjili and CH92/105. The overall ranking of the genotypes for stability using the four stability parameters showed that the overall most stable genotypes for ash content of starch were 81/00015, CH92/112, LCN8010, 30786, CH92/108, Silira, Gomani and Mkondezi (Table 7). Spearman's coefficient of rank correlation (Table 6) showed that Wi-ecovalence was significantly and positively correlated to stability variance – no covariate. The other stability parameters were not correlated hence each one stood on its own and could not displace the other.

The overall rank was not correlated to cultivar superiority measure but was significantly correlated with Wi-ecovalence and stability variance – no covariate. With

respect to ash content, AMMI was not correlated to the overall rank stability. The stability parameter that was closest to the overall rank was Wi-ecovalence, followed by stability variance – covariate (Table 8). The genotypes that were stable suggest that their starch ash content was not dependent on environment. The AMMI analysis showed that Gomani, Mbundumali, 30786, CH92/082 and MK95/054 were best suited to Makoka while 83350, CH92/108, TME1, TMS4(2)1425 and TMS60121 were best suited to Chitedze. The results show that either Wi-ecovalence or stability variance – no covariate can be used for stability analysis for ash content in starch.

Industrial use and regulation of native cassava starch in Malawi. David Whitehead and Sons Limited is a textile manufacturing

company, which revealed that they normally use cornstarch, which is difficult and expensive to acquire. The company switched to a powder so called cassava starch obtained from local traders. The product was giving under-sized warp yarns and also caused clogging on the machines when weaving the cloth (Fungulani and Maseko, 2001). This study revealed that the powder was cassava flour and not cassava starch as the traders claimed. The use of native cassava starch, gave very good results (Fungulani and Maseko, 2001) in the sense that it produced the right size of warp yarns, no clogging was experienced on the machine, and the cloth was of high quality (it was smooth and pure white).

Packaging Industries (Malawi) Limited (PIM) is a company that produces a range of corrugated cartons used for packaging of different products for local distribution and

Table 8: Summary of stability statistics for ash content in starch from 20 Malawi cassava genotypes, which were tested at Chitedze and Makoka in 2000/01 season.

Genotype	Cultivar superiority		Wi-Ecivalence		Stability variance -no covariate		AMMI		Overall rank
	Pi GxE Stat.	Rank	Wi GxE Stat.	Rank	δ^2_i GxE Stat.	Rank	IPCA scores	Rank	
Silira	0.1200	7	0.2379	13	0.1710	14	0.0072	1	5
Sauti	0.3222	19	0.3425	16	0.2485	16	-0.0701	8	16
CH92/082	0.1254	8	0.1642	11	0.1164	12	-0.1474	12	11
TMS4(2)1425	0.2616	17	0.0421	6	0.0260	7	0.1474	12	10
CH92/112	0.1599	12	0.0111	3	0.0030	2	0.0073	2	2
CH92/105	0.2451	16	0.0430	7	0.0266	8	-0.0314	5	6
LCN8010	0.1018	4	0.0150	4	0.0058	4	0.0846	9	3
30786	0.1152	6	0.0091	2	0.0015	1	-0.1474	12	3
83350	0.3182	18	0.3338	15	0.2420	6	0.1619	13	13
TME1	0.2110	15	0.2379	13	0.1710	14	0.1474	12	15
81/00015	0.1313	9	0.0002	1	-0.0051	3	0.0121	3	1
CH92/108	0.0000	1	0.0351	5	0.0207	5	0.1377	11	4
MK95/054	0.0770	3	0.2548	14	0.1835	15	-0.1329	10	10
Mbundumali	0.1893	13	0.1700	12	0.1206	13	-0.1619	13	12
Gomani	0.0640	2	0.0869	9	0.0591	10	-0.2199	14	5
Mkondezi	0.1537	10	0.0929	10	0.0635	11	0.0266	4	5
TMS60121	0.1044	5	0.0869	9	0.0591	10	0.1474	12	6
TMS84563	0.2040	14	0.3567	16	0.2590	17	-0.0556	6	14
Maunjili	0.3901	20	0.0857	8	0.0582	6	0.0266	4	7
TMS60142A	0.1578	11	0.0929	10	0.0635	11	0.0604	7	8

exports. Major users of the cartons are soap, oil, confectionery, textile and garment manufacturing industries, and tobacco processing firms (Itaye, 2001). Cassava products in the name of starch has been used in the past but their use was discontinued in 1966 due to the fact that local producers of this type of starch were not able to consistently supply the company in accordance with its required quality standards (Itaye, 2001). Due to high landed cost of the imported cornstarch, PIM has been looking for alternative sources of supply. It is for this reason that PIM collaborated with the University of Malawi in 1997 to assess the possibility of use of cassava starch. When the properly extracted cassava starch was used, and the results were successful (Itaye, 2001; Peter Chingo and Yoweli Kawiya, personal communication).

Nzeru Radio Company Limited is a company that uses starch in manufacturing of batteries (dry cells). The starch quality requirements include low iron levels, a maximum protein content of 0.50 %; a maximum ash content of 0.50 %; maximum moisture content of 15 %; maximum acid insolubles of 0.10 %; and should have a pH within the range of between 4.5 and 6.0. Then native cassava starch was brought. The paste made using native cassava starch passed the tests for pH, viscosity and specific gravity. Then batteries were successfully made on 30th January 2002. No problem was experienced in the course of making the batteries, and the paste was just like cornstarch in terms of fluidity and viscosity. The batteries were tested after one, six, 10 and 12 months after making, the cells that were made using cassava starch were still fine and the Zinc canes (the negative part of the battery) were intact, that is, not eaten away or corroded.

Malawi Pharmacies Limited (MPL) is a pharmaceutical company which manufacture drugs using both artificial and natural products. Native cassava starch was brought to MPL for trial. It passed all the tests and tablet making was successful. The compression for making the tablets was similar

to the ones made from cornstarch. The disintegration of the tablets was also tested. Normally, tablets need to disintegrate within 4-15 minutes and they did pass even after one month of making. The tablets also passed the friability test, where 10 tablets are put in a machine and the machine is run for five minutes. The loss in weight was far less than 2 %. From these results, it was concluded that use of cassava starch in tablet making was possible.

Malawi Bureau of Standards (MBS) is a policing body for quality control of products and services in Malawi. It was found that MBS had neither the international nor national standards for starch. It was then agreed that they were going to source international standards and try to come up with national standards for starch. Hence, MBS needs to be committed in the quality control of cassava starch for it to be taken up by industries for use in their industries without hesitation.

Implications and Conclusions

This study is expected to enhance the harnessment of local markets for starch before thinking of export opportunities. The inclusion of industries in this study in a participatory manner cleared the doubt they had on cassava starch. As a result of this study industries are looking forward to getting suppliers for proper native cassava starch. The use of locally produced starch may entail in reduction of cost of production which may in turn lead to reduction of prices for products for consumers. The demand for local products like cassava starch is likely to push up the production of cassava in general in Malawi.

The genotypic influence on root dry matter is much greater than for the environment. This agrees with the hypothesis that one or a few major genes control root dry matter in cassava. Rainfall distribution affected the starch extraction from cassava roots. The more evenly the rain is distributed throughout the season, the wider the harvesting time for roots to achieve high starch extraction rate. All the cassava

genotypes produced starch that had no protein, and their ash and moisture contents were much lower than the recommended maximum. Hence, cassava starch was of high quality in terms of protein, ash and moisture content. The whiteness and pH of cassava starch too were within the recommended range. The four stability parameters that were applied for starch moisture and ash content, and pH were compared using Spearman's coefficient of rank correlation. The AMMI was correlated to other measured stability parameters, and it also allocates unstable genotypes to their appropriate environments. AMMI is therefore recommended for use in stability analysis of starch quality parameters. It was also found that native cassava starch is suitable for use in the major industries which use cornstarch in Malawi but strict quality control need to be instituted to avoid cheating.

Way Forward

Further studies to isolate genes and markers responsible for root dry matter are required in order to facilitate marker assisted selection. Further studies on determination appropriate period to harvest cassava for starch extraction in different agroecologies are needed. This will facilitate maximisation of starch extraction. There is need to organise farmers and link the producers/processors to industries which need the products in question like cassava starch.

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La menace de la pandémie de la mosaïque du manioc sur la production et ses conséquences au Burundi

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Resume. Le manioc (*manihot esculenta*) joue un rôle vital dans la sécurité alimentaire des populations burundaises. C'est l'une des cultures vivrières les plus largement cultivées, capable d'atténuer les effets des conditions climatiques défavorables sur les autres cultures moins tolérantes. Aussi, toute menace sur sa production doit être sérieusement considérée. Une pandémie de la mosaïque du manioc d'une sévérité inhabituelle qui a dévasté la production du manioc dans beaucoup de régions en Afrique de l'Est a été signalée pour la première fois au Nord-Ouest de la Tanzanie en 1998, puis au Rwanda en 2001. Les deux pays étant frontaliers du Burundi, il y avait une grande inquiétude de sa probable expansion dans le pays. Une enquête menée dans les champs de manioc en juin 2003, qui comprenait aussi le diagnostic des virus sur des échantillons de feuilles issues des plants malades, a montré pour la première fois que la pandémie et le virus lui associé, EACMV-UG, avaient déjà gagné le Burundi à partir du Nord-Est et continue à se répandre vers le centre et l'Est du pays. Cette situation laisse envisager des changements dramatiques avec une forte chute de la production, comme cela a été le cas dans les autres pays affectés, si des mesures urgentes ne sont pas prises pour combattre la maladie. Les approches mises en œuvre pour venir à bout de ce problème posé par cette pandémie comprennent l'acquisition, la multiplication et la distribution des variétés de manioc améliorées résistantes à la mosaïque, en collaboration avec l'EARRNET

et l'IITA. Ce processus a déjà commencé avec l'introduction, l'évaluation et la multiplication de 81 clones élités obtenus du programme de développement du germoplasme de l'EARRNET basé en Ouganda. Parallèlement, un programme de formation des agriculteurs et des agents de la vulgarisation sur les méthodes de lutte contre cette maladie a été initié. Nous espérons que ces mesures pourront atténuer les effets de cette pandémie, mais des moyens complémentaires tant locaux qu'extérieurs restent nécessaires pour apporter une réponse adéquate à cette crise.

Introduction

Avec une population estimée à 6,65 millions de personnes en 2000, le Burundi vit essentiellement de l'agriculture. Le manioc est la troisième principale culture vivrière du pays. Il occupe à lui seul 10% des superficies sous cultures vivrières et 50% des superficies sous plantes à racines et tubercules. Sa production était estimée à 713.000 tonnes sur une superficie de 80.000 ha (FAOSTAT, 2002). Au regard de son importance, toute menace sur sa production doit être ressentie comme une menace à la sécurité alimentaire, et de ce fait être sérieusement considérée. Parmi les contraintes à la production du manioc, la maladie de la mosaïque du manioc vient en première position (Bigirimana et Mbwika, 2001). Néanmoins, la production est restée satisfaisante jusqu'à l'heure actuelle malgré la présence de cette maladie.

Une épidémie de la mosaïque du manioc accompagnée d'une sévérité inhabituelle a été signalée pour la première fois en Tanzanie en 1998 (Legg, 1999), puis elle a continué à se répandre dans bon nombre de pays en Afrique Orientale et Centrale où elle a dévasté la culture. En 2001, cette épidémie associée à la présence d'une souche de virus de mosaïque plus virulente, EACMV-UG, a été signalée pour la première fois au Rwanda (Legg *et al.*, 2002). Compte tenu de la proximité de ces deux pays vis-à-vis du Burundi, une menace de cette épidémie était sentie comme imminente dans le pays. Aussi, à partir de 2001, des mesures de lutte ont été initiées. Cependant, en vue de connaître les zones d'intervention, une enquête était indispensable pour avoir des informations complètes quant à la présence de cette souche et sa distribution dans le pays. Ce travail a été fait par une équipe du programme de recherche sur le manioc à l'Institut des Sciences Agronomiques du Burundi (ISABU), tandis que l'analyse de l'ADN a été effectuée au laboratoire de virologie de 'the International Institute of Tropical Agriculture, Eastern and Southern Africa Regional Centre (IITA-ESARC)'.

Methodologie

L'enquête a été conduite au mois de juin 2003, dans 10 provinces sur les 16 qui comptent le pays. Elle a été menée dans des champs de manioc des agriculteurs. Dans chaque site, les données suivantes ont été collectées : la taille du champ, la latitude et la longitude du site, les cultures en association, les variétés de manioc se trouvant dans le champ et la variété ayant fait objet d'échantillonnage de feuilles atteintes de mosaïque. Pour ce qui est de l'évaluation des maladies, 30 plants par champ ont fait objet d'observations et les données suivantes ont été collectées : le nombre de mouches blanches *Bemisia tabaci* (vecteur de la maladie de la mosaïque du manioc), le type d'infection virale (due aux boutures ou à la mouche blanche) et la sévérité de la mosaïque du manioc, la sévérité

de la bactériose vasculaire, le nombre d'acararien vert *Mononychellus tanajoa*, la sévérité de l'acariose, le nombre de cochenille *Phenacoccus manihoti*, la sévérité de la cochenille farineuse et la présence ou non de *Typhlodromalus aripo* (prédateur phytoséiide). L'évaluation de la sévérité des maladies a été faite en utilisant l'échelle standard de 1 à 5 (Hahn *et al.*, 1980). Pour les feuilles issues des plants malades, deux échantillons ont été pris par champ et ont été placés dans des micro tubes, puis stockés dans une glacière. Pour chaque échantillon, le type d'infection virale et la sévérité ont été enregistrés. Les mouches blanches ont été collectées dans chaque champ à l'aide d'un aspirateur, puis transférées dans un tube contenant de l'éthanol.

L'ADN a été extrait des échantillons de feuilles atteintes de mosaïque en utilisant un kit d'extraction mobile et la méthode de Dellaporta *et al.* (1983). Les extraits d'ADN précipités ont été ensuite conservés dans de l'éthanol à 70% puis envoyés au laboratoire de virologie de l'IITA-ESARC pour être analysés à l'aide des techniques PCR 'polymerase chain reaction' et RFLP 'restriction fragment length polymorphism' utilisant des marqueurs spécifiques pour le virus Africain de la mosaïque du manioc (ACMV), le virus Est Africain de la mosaïque du manioc (EACMV) et la souche ougandaise d'EACMV (EACMV-UG).

Resultats

La synthèse des résultats est présentée dans le Tableau 1. La bactériose vasculaire n'a été observée dans aucune province ayant fait objet d'enquête, tandis que la cochenille farineuse n'a été observée que dans la plaine de Bujumbura autour du lac Tanganyika où elle ne cause pas de dégâts économiquement importants. L'acararien vert a été observé de façon modérée dans la quasi-totalité des sites ayant fait objet d'enquête. Notons que les deux ravageurs sont contrôlés par lutte biologique sur une bonne partie du territoire.

La distribution des souches de virus causant la maladie de la mosaïque du manioc au Burundi est montrée dans la Figure 1.

Discussion

L'incidence de la Mosaïque. L'incidence est très élevée dans la région Nord-Est du Burundi comprenant les provinces de Kirundo (84,6

%) et de Muyinga (74,7%). Ces résultats sont caractéristiques d'une situation épidémique. Le reste des provinces connaissent une sévérité qui passe du modéré au faible : Rutana (56,1%), Bujumbura rural (54,3%), Ruyigi (44,5%), Ngozi (38,6%), Karuzi (28,7%), Gitega (28,2%), Kayanza (20%), Muramvya (18,5%).

Tableau 1: Synthèse des résultats de l'enquête et de l'analyse de l'ADN.

Province	Sévérité	Infection Mouche (%)	Infection Boutures (%)	Incidence (%)	Nombre de mouche/plant	Virus
Bujumbura	2,8	17,7	36,6	46,3	0,5	ACMV, EACMV
Kayanza	3,0	3,5	16,5	20,0	0,3	ACMV, E-UG ¹
Ngozi	3,1	18,6	20	38,6	0,5	ACMV, E-UG
Kirundo	4,0	48,3	36,3	84,6	7,3	ACMV, E-UG
Muyinga	4,1	54	20,7	74,7	1,8	ACMV, E-UG
Karuzi	3,3	13,4	14,6	28,0	1,1	ACMV, E-UG
Gitega	3,4	16,6	11,6	28,2	0,5	ACMV, E-UG
Muramvya	3,8	3,5	15,0	18,5	0,1	ACMV
Ruyigi	3,5	15,5	29	44,5	3,7	ACMV, E-UG
Rutana	3,5	12,3	43,8	56,1	0,5	ACMV, E-UG

¹ EACMG-UG.

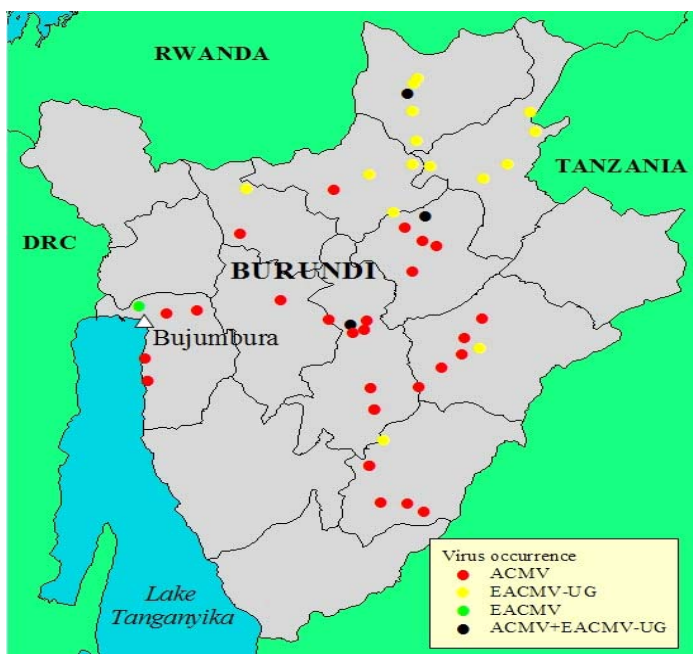


Figure1: Carte de distribution des virus de la mosaïque du manioc.

Type D'infection De La Mosaïque. L'infection due à la mouche blanche est plus élevée que celle due aux boutures dans 22 sites ; l'inverse s'observe dans les 31 autres sites. Ceci montre que la plupart des infections dans les champs des agriculteurs sont dues à l'utilisation d'un matériel de plantation déjà infecté. Néanmoins, les provinces du Nord-Est (Kirundo et Muyinga) connaissent de fortes proportions d'infections dues à la mouche blanche, comparativement aux autres provinces, avec une incidence moyenne y relative de 48,3% pour Kirundo et 54% pour Muyinga. Ceci prouve que la maladie de la mosaïque du manioc est en train de se répandre de façon plus active dans les provinces du Nord-Est du pays.

La Severite de la Mosaïque. D'une façon générale, la sévérité enregistrée dans les champs ayant fait objet d'enquête est assez élevée. Elle est supérieure à 3 dans 43 sites sur les 53. Encore une fois, les provinces du Nord-Est connaissent des symptômes de mosaïque très sévères dans les champs (moyenne de 4,0 pour Kirundo et de 4,1 pour Muyinga) comparativement aux autres provinces. Ceci prouve à suffisance que la maladie de la mosaïque du manioc constitue une menace majeure, et plus particulièrement dans la partie Nord-Est du pays qui est la plus affectée.

Le Nombre de Mouches Blanches. Les mouches blanches sont abondantes dans les provinces du Nord-Est (7,3 en moyenne pour Kirundo), ce qui explique la forte incidence des infections secondaires dues au vecteur de la maladie de la mosaïque du manioc dans les champs. Ailleurs dans les autres provinces ayant fait objet de l'enquête, on trouvait très peu de mouches dans les champs.

Diagnostic Des Virus. Le test s'est révélé positif sur tous les échantillons pris dans les 53 sites. ACMV est présent dans 34 sites, EACMV-UG dans 17 sites, EACMV dans un seul site (plaine de la Rusizi), et un mélange de EACMV-UG + ACMV dans 5 sites

(Muyinga, Kirundo, Ruyigi et Ngozi). EACMV-UG est présent dans tous les sites de la région Nord-Est du Burundi en provinces de Kirundo et Muyinga. Il a été également observé dans des certains sites des provinces du centre (Nord de Gitega et de Karuzi), du Nord (Ngozi et Kayanza) et de l'Est (Ruyigi et Nord de Rutana). La quasi- totalité des plants infectés par EACMV-UG ont une infection due aux mouches blanches. Ces résultats montrent qu'il y a une expansion rapide de EACMV-UG associée à une mosaïque très sévère dans la région Nord-Est du Burundi. La présence de EACMV-UG dans les provinces du nord, du centre et de l'Est laisse présager des changements similaires en terme de l'épidémiologie de la maladie de la mosaïque du manioc dans ces sites. Cependant, l'incidence de la mosaïque reste modérée dans ces localités.

Conclusion

Les provinces ayant fait objet d'enquête peuvent être divisées en 3 zones selon la situation de la maladie de la mosaïque du manioc et les souches de virus présentes. Des approches de contrôle convenables à chacune sont proposées.

Zone 1. Elle comprend les sites ayant la présence de ACMV uniquement, avec une incidence relativement faible. Ce sont les sites du Sud Gitega, Sud Rutana, Muramvya et Bujumbura rurale.

Il s'agit de la zone la moins touchée et dont les infections sont spécialement dues à l'utilisation d'un matériel de plantation déjà infecté. Les mesures de contrôle de la maladie de la mosaïque du manioc dans cette zone devraient être d'ordre phytosanitaire en sélectionnant des boutures saines pour la plantation et en épurant les plants atteints. Cependant, compte tenu de la taille du pays relativement petite qui favorise une expansion rapide de l'épidémie, il est nécessaire d'identifier un germoplasme résistant à la mosaïque pour cette zone.

Zone 2. Elle comprend les provinces Ngozi, Kayanza, Karuzi, Ruyigi, Nord Gitega et Nord Rutana. L'incidence y est modérée avec une présence occasionnelle de EACMV-UG et omniprésence de ACMV. C'est une zone où l'épidémie est appelée à s'étendre dans un proche avenir. Il est donc nécessaire d'y faire un suivi régulier pour connaître l'évolution des changements déjà prévisibles.

Les mesures de contrôle sont similaires à celle de la zone 1 à court terme, mais la progression de l'épidémie de la maladie de la mosaïque associée à la présence de EACMV-UG dans cette zone laisse plutôt recommander aux agriculteurs de recourir à des cultivars moins sensibles. Parallèlement, des essais d'évaluation et d'identification des variétés résistantes à la maladie et adaptées à cette zone doivent être menés par l'ISABU.

Zone 3. Il s'agit de la région Nord-Est du pays, comprenant les provinces de Kirundo et Muyinga. Elle connaît déjà l'épidémie de la maladie de la mosaïque du manioc associée à la prédominance de EACMV-UG. Les symptômes sont très sévères et l'incidence très élevée. On observe également une abondance de mouches blanches *B. tabaci*. Cette zone nécessite une attention particulière, et les mesures de contrôle de la mosaïque doivent recourir à l'utilisation des variétés résistantes, étant donnée que les infections dans les champs sont presque toutes secondaires, et partant dues au vecteur.

Ainsi, l'ISABU doit aider à l'identification, la multiplication et la distribution de telles variétés dans cette zone, faute de quoi, les agriculteurs ne pourront plus cultiver du manioc avec leurs cultivars locaux.

Les Conséquences de Cette Epidémie et les Mesures Prises

L'apparition de l'épidémie de la maladie de la mosaïque du manioc liée à la présence de EACMV-UG dans la région Nord-Est du Burundi et sa progression vers le Centre-Est et le Nord du pays laisse augurer des

changements dramatiques, dont les retombées sur la production du manioc risquent d'être catastrophiques si des mesures urgentes ne sont pas prises. En effet, en tenant compte de ses aptitudes à produire des rendements permettant de survivre lorsque les conditions climatiques souvent défavorables dans ce pays provoquent l'échec des cultures de céréales et de légumineuses, cette épidémie risque de compromettre sérieusement la sécurité alimentaire des populations burundaises qui connaissent déjà un déficit alimentaire depuis plusieurs années. Pour pallier cette situation, il est important que les principales parties prenantes dans la culture du manioc élaborent et mettent en application des stratégies de lutte contre cette maladie.

A l'ISABU, les mesures déjà prises pour combattre cette épidémie sont de trois ordres :

La multiplication et la distribution des variétés résistantes à la mosaïque du manioc.

Cette activité a commencé avec l'acquisition de 81 clones en 2000 à partir du programme de développement du germoplasme de l'EARRNET basé en Ouganda. Ces clones ont été d'abord évalués dans différentes zones agroécologiques afin de confirmer leur adaptation et leur résistance à la mosaïque du manioc.

A l'issue de cette étape, 57 clones se sont révélés performants et font actuellement objet de multiplication. Ils couvrent 3ha et la première coupe des boutures se fera au cours de cette année 2003. Il est attendu 150.000 tiges de matériel de plantation.

Formation des agriculteurs et des agents de la vulgarisation sur la lutte contre la maladie de la mosaïque du manioc. Cette activité a été initiée en 2003 avec le projet '*Office for US Foreign Disaster Assistance CMD Project*'. Jusqu'à présent, 23 cadres des services de la vulgarisation pris dans toutes les provinces ont été formés. A leur tour, ils ont formé 480 agriculteurs responsables des associations d'agriculteurs.

Tableau 2: Résultats de l'évaluation des maladies 6 mois après la plantation.

Clone	No W ¹	CGM ² sévérité	CM ³ sévérité	Infection ⁴	CMD ⁵ sévérité	CMD incidence (%)
MM96/ 0619	90	1	1	W	4	100
MM96/7688	324	1	1	H	1	0
MM96/ 2266	210	1	1	W	2	100
MM96/ 3165	233	1	1	W	5	100
MM96/ 4722	280	1	1	W	2	95
ABBEY-IFE	90	1	1	H	1	0
MM96/7204	115	1	1	H	1	0
MM96/2352	113	1	1	W	5	100
Local	-	1	1	W	5	100
MM96/0735	130	1	1	H	1	0
MM96/ 8299	180	1	1	H	1	0
MM96/ 0287	94	1	1	H	1	0
MM96/ 5533	158	1	1	W	2	30
MM96/ 5280	142	1	1	H	1	0
MM96/ 2085	193	1	1	W	2	35
MM96/ 0181	204	1	1	W	2	35

¹nombre de mouches blanches, ²acarien vert du manioc, ³cochenille farineuse du manioc, ⁴infection due à la mouche (W) ou sain (H), ⁵maladie de la mosaïque du manioc

Evaluation des clones élités dans une zone à haute pression de la mosaïque du manioc.

Les suspicions de la présence de l'épidémie de la maladie de la mosaïque du manioc associée à la présence d'EACMV-UG dans la région Nord-Est frontalière avec le Rwanda, bien avant la confirmation par l'enquête, nous ont poussé à évaluer en province de Kirundo, 15 clones de l'EARRNET les plus performants sur les 57 en multiplication. Les résultats sont encourageants dans la mesure où 7 clones sur 15 se sont montrés résistants à la mosaïque du manioc (Tableau 2).

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Effect of shade and intercropping in the management of sweetpotato virus disease in Uganda

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Abstract. Experiments were conducted in Uganda for two seasons during 2002 to investigate the effect of intercropping and shade on activities of whiteflies (*Bemisia tabaci*), the main vector of sweetpotato virus disease (SPVD). SPVD is the major disease constraining sweetpotato production in Uganda. The intercrop experiment consisted of the following treatments: sweetpotato sole, sweetpotato + maize, maize sole, sweetpotato + trap, sweetpotato + maize + trap and unplanted plot with trap. Traps were used to monitor whiteflies abundance in different treatments. Traps consisted of bright yellow sticky strip wrapped on 10-cm diameter plastic tubes 30 cm from the ground. For the shade experiment, sweetpotato plots of 5 x 5 m were established with temporary shade made of papyrus mats 1.5 m above the ground. Treatments under the shade trial were sole sweetpotato, sweetpotato + trap, sweetpotato + shade, sweetpotato + shade + trap, shade + trap and empty plot with trap. There were significantly more nymphs and adult whiteflies on sweetpotato in sole than in the sweetpotato maize intercrop plots. Traps located in sole sweetpotato plots also captured higher numbers of whiteflies. However, mean number of plants with SPVD symptoms was similar in intercropped and sole sweetpotato plots. There was no significant difference in storage root yield for intercropped sweetpotato and sole sweetpotato. Maize yield was not affected by intercropping. Shade did not have a significant effect on number of whiteflies, nymphs or infected plants but shaded plots

yielded least in both seasons. This work shows that maize may act as a guard crop without being affected or affecting sweetpotato crop yet checking on SPVD vectors, the whiteflies.

Introduction

Sweetpotato virus disease (SPVD) remains the most single important disease of sweetpotato, occurring whenever the crop is grown (Geddes, 1990; Carey *et al.*, 1999). Ngeve and Bouwkamp (1991) reported loss associated with yield to have ranged from 0-90% in a three-year field study of SPVD. SPVD results when two viruses: the non-persistently aphid-transmitted virus *Sweetpotato feathery mottle virus* (SPFMV) (Potyviridae: *Potyvirus*) and the semi-persistently whitefly-transmitted *sweetpotato chlorotic stunt virus* (SPCSV) (Closteroviridae: *Crinivirus*) co-infect sweetpotato at the same time (Gibson *et al.*, 1998). SPCSV synergises the infection of SPFMV (Karyeija *et al.*, 1998) and appears to be the key in the spread of SPVD, being closely associated with the prevalence of whiteflies on crops (Aritua *et al.*, 1999). According to Moyer and Salazar (1989) virtually all sweetpotato grown from nonvirus-tested materials revealed the presence of one or more viruses. Often, farmers have practiced cultural methods knowing or unknowingly which has resulted in farmers keeping the incidence of this disease quite low, though some local cultivars have been lost due to the same disease. Notably among the practices are selections of 'clean' planting

material (personal observation), intercropping (Ndunguru *et al.*, 2000) and use of shade (Gibson, pers. Communication). Although scanty information exists on selection and shade in management of diseases, a lot has been reported on intercropping (Gold, 1990; Ekesi *et al.*, 1999; Khan, *et al.* 2000).

Intercrops have been reported to reduce pest incidence and damage to the principle crop (Trenbath, 1993; Baliddawa, 1995) and in Uganda, have been reported as a component of IPM strategies for beans (Kyamanywa and Tukahirwa, 1988; Ogenga-Latigo *et al.*, 1992). Also studies by Ekesi *et al.* (1999) provided some evidence that intercropping improved control of thrips on cowpea by the entomo-pathogenic fungus *Meterhizium animsopliae*. Intercropping maize with napier grass and *Desmodium* sp. in Kenya has been proposed against *lipidopteran* stem borers and striga (Khan, *et al.* 2000). Intercropping the tropical rootcrop cassava with maize or cowpeas resulted in lower whitefly populations of the two species, *Aleurotrachelus socialis* and *Trialeurodes variabilis* compared to monocropped cassava. Higher whitefly populations preferred the more vigorous monocropped cassava (Gold *et al.*, 1990).

Also reports indicate whiteflies are weak fliers, relying on air currents for both short and long distance migration (Byrne & Bellows 1991, Byrne *et al.* 1996). Several tall-growing non-host plants, primarily in the family Gramineae, have been tested as barrier crops or intercrops to reduce whitefly colonization and virus transmission among main crops mainly on vegetables. Maize as an intercrop in sweetpotato is hoped to limit activities of whiteflies hence limiting spread of SPVD. This work was set to evaluate the effect of maize crop as a barrier and temporary shade in the management of whiteflies

Materials and Methods

The trials were planted at Namulonge Agricultural and Animal production Institute (NAARI) for two seasons. First planting was

done on 30/4/2002 and the second 16/9/2002. Treatments were sole sweetpotato (cultivar 'Tanzania'), sweetpotato + maize, maize sole, sweetpotato with sticky traps, sweetpotato + maize with sticky traps, empty plot with sticky trap. Vine cuttings of cultivar 'Tanzania' infected with SPVD were planted around experimental plots to provide infector inoculum. Plot size was 5 x 5 m and planting was done on ridges with intra-row spacing of 15 cm. Maize was planted between ridges and 15cm within the rows. The design used was complete randomized block with 4 replications. Sticky traps made of bright yellow plastic (Oecos Ltd, UK: Yellow roller traps) double adhesive stripes 75 mm wide wrapped at 50 cm above the ground on 60 cm plastic poles were used to improve the whiteflies estimates in intercropped and non intercropped plots. One trap was placed at the centre of each treatment. The sticky tape would be changed every after data taking. For the shade experiment, treatments were trap in empty plot, trap with shade, trap + sweetpotato + shade, sweetpotato alone, sweetpotato + trap and sweetpotato + shade, making six plots in all. Covers made from papyrus mats placed approximately 1.5 m above the ground were raised on plots to provide temporally shade. Trap setting was as above. The following data were collected: number of sweetpotato plants infected per week, number of whitefly nymphs on sweetpotato on 4 randomly selected plants once a week, number of adult whiteflies on sweetpotato on two ridges once a week, number of whiteflies on traps twice a week. At harvest (three and half months for maize, five months for sweetpotato) grain yield and storage root yield were recorded.

Results and Discussion

Nymphs, adult whiteflies and infected plants in intercropped and non-intercropped plots.

Number of nymphs and adult whiteflies on middle two ridges and mean number infected plants are shown in Table 1. There were significantly more nymphs and adult whiteflies in sole sweetpotato compared to

the intercropped sweetpotato plots. However, mean number of plants with SPVD symptoms was similar. Similarly, there was significantly high number of whiteflies trapped in plots with sole sweetpotato compared to the intercropped ones (Table 2). This may be a result of the shielding effect of maize that possibly interfered with the movement of whiteflies. This result concurs with findings of Gold (1990) that intercropping cassava with maize or cowpea resulted in lower whitefly populations of the two species, *Aleurotrachelus socialis* and *Trialeurodes variabilis* compared to monocropped cassava. Although Hugh and McSorley (1997) reported limited effect of corn as a barrier crop

in beans in the management of whiteflies, use of maize in sweetpotato appears to be effective in reducing numbers of whiteflies infesting the crop.

Storage root yield of sweetpotato and grain yield of maize. There was no significant difference in storage root yield for intercropped sweetpotato and sole sweetpotato (Table 3). The first season had poor yield because of drought that set in early in the season. The yield of maize was not affected by intercropping. Both intercropped and sole maize plots had statistically similar grain yield. This is similar to results obtained when maize was intercropped with cauliflower

Table 1: Nymphs, adult whiteflies and infected plants in intercropped and non-intercropped plots during the two seasons 2002a and b.

Treatment	No. nymphs	Adult whiteflies (two middle row)	Infected plants
2002a			
Sweet potato	5.88a	49.64a	0.39
Sweet potato/maize	3.99b	26.0b	0.33
LSD (0.05)	1.5	8.5	NS
CV (%)	64.6	47.7	
2002b			
Sweet potato	5.3a	88.4a	0.71
Sweet potato/maize	3.4b	38.6b	0.68
LSD (0.05)	1.4	15.1	NS
CV (%)	69.9	50.3	

Table 2: Mean number of whiteflies trapped in sweet potato/maize plots during the two seasons 2002a and b.

Treatment	No. of whiteflies	
	2002a	2002b
Sweet potato/trap	47.3a	50.63a
Sweet potato/trap/maize	42.9a	35.14b
Trap	32.4b	26.84c
LSD (0.05)	4.95	5.68
CV (%)	28.7	34.19

Table 3: Storage root and grain yield of sole and intercropped sweet potato and maize during 2002a and b.

Treatment	Marketable storage root weight (t/ha)	Maize yield (t/ha)
2002a		
Sweet potato/Trap	5.7	
Sweet potato	5.1	
Sweet potato/Maize	3.4	0.96
Sweet potato/Maize/trap	3.1	0.87
Maize		0.72
LSD (0.05)	NS	NS
CV (%)	48.5	26.8
2002b		
Sweet potato/Trap	11.49	
Sweet potato	9.10	
Sweet potato/Maize	6.41	2.52
Sweet potato/Maize/trap	5.65	2.96
Maize		2.37
LSD (0.05)	NS	NS
CV (%)	74.39	19.65

(Kasetsart, 1997). Gold *et al.* (1990) also reported similar findings that a maize intercrop did not affect yield of cassava. The fact that maize does not affect the yield of sweetpotato means that farmers can use the intercrop to manage whiteflies without losses in yields of either crop.

Effect of shade on adult whiteflies, nymphs, SPVD and yield. Shade did not have a significant effect on number of whiteflies and nymph populations and mean SPVD infected plants. However, there were slightly more adult whiteflies in unshaded plots than the shaded ones in both seasons (Table 4). In the second season, there were significantly more nymphs in shaded plots than unshaded. Trap catches varied significantly with treatment. Shaded plots had fewer whiteflies trapped in both seasons (Table 5). Shade did not have any effect on adult whiteflies and nymphs in the first season probably due to high rainfall, compared to second season, which was relatively dry. The more nymphs recorded in

shaded plots of sweetpotato in the second season could have been due to microclimate effects created under shade favouring oviposition.

Yield varied significantly, unshaded plots yielding highest and shaded least in both seasons (Table 6). Weight of vines was not significant in the first season (probably due to poor weather) but varied in second season with shaded plots having least weight. Also the mean number of marketable storage roots per plant was lowest in shaded plots. Shade encourages vegetative growth and therefore affects yield. In addition, less radiation reaches the leaves in shaded plots, reducing the net Photosynthetically Active Radiation (PAR), hence affecting yield. Abdel-Mawgoud *et al.* (1995) found out that shade reduced total dry matter production significantly although it did not affect the fruit yield in tomatoes.

This work has shown that intercropping sweetpotato with maize does not affect yield of either crops. It also shows that maize acts

Table 4: Nymphs, adult whiteflies and mean infected plants in shaded and unshaded sweet potato plots during 2002a and b.

Treatment	Season					
	2002a			2002b		
	Number of adult whiteflies on two middle ridges	Average no. of nymphs	Average no. of infected plants	Number of adult whiteflies on plants	Average no. of nymphs	Average no. of infected plants
Shade	2.69	0.26	0.48	63.03	31.87a	0.13
Unshaded	3.56	0.22	0.30	52.89	6.25b	0.19
LSD (0.05)	NS	NS	NS	NS	8.9	NS

Table 5: Whiteflies on traps placed in shaded, empty and sweet potato plots during 2002a and b.

Treatment	Number of adult whitefly on trap	
	2002a	2002b
Sweet potato/trap	7.39a	12.89a
Trap	9.22a	9.37b
Shade/trap/sweet potato	2.17b	7.45b
Shade/trap	1.69b	4.45c
CV (%)	89.7	55.2

Table 6: Weight of vines, average marketable storage roots/plant and marketable fresh weight in shade and unshaded plots of sweet potato during 2002a and 2002b.

Treatment	Weight of vines (5plants)	Average marketable	Storage roots/plant
2002A			
Marketable yield (t/ha)			
Sweet potato/shade	9.2	0.16b	1.49b
Sweet potato	8.9	0.78a	10.52a
Sweet potato trap	8.0	0.67a	9.04a
Sweet potato/shade/trap	6.4	0.22b	2.24b
LSD		0.25	3.42
2002B			
Sweet potato/shade	8.23c	0.21b	1.64b
Sweet potato	21.23a	1.80a	13.80a
Sweet potato trap	12.93b	1.40ab	13.06a
Sweet potato/shade/trap	4.47c	0.21b	1.64b
LSD	4.69	1.33	11.76

as a barrier to movement of whiteflies. This could further be explored by altering dates of planting and spacing. The shade effect on yield was significant. Farmers may plant under shade to conserve planting material but it may not be effective as a management option for controlling sweetpotato virus disease.

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Evaluation of orange-fleshed sweetpotatoes varieties for resistance to sweetpotato virus disease

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Abstract. Use of orange-fleshed sweet potatoes (OFSP) rich in β -carotene, a precursor for vitamin A in the body, is being promoted as a food based approach to combat vitamin A deficiency in diets among vulnerable communities in Uganda. A number of OFSP varieties have been identified and tested. However, sweetpotato virus disease (SPVD) is a major production constraint in Uganda and most of the introduced OFSP materials have succumbed to the viral damage. It is important that before the OFSP are passed to the farmers they are evaluated for desired attributes. Thus experiments were conducted to evaluate different promising OFSP varieties in Uganda. These included SPK004, Zapallo, Naspot5, Ejumula, and Kala. New kawogo served as a SPVD-resistant, the control. The trial was laid out in a randomized complete block design with varieties as treatments replicated four times. Mean number of plants with SPVD symptoms varied among varieties with New Kawogo being least affected. Total fresh weight, marketable weight and mean number of storage roots per plant varied significantly among varieties. The local cultivar Ejumula had a high yield but also had a high incidence of SPVD. Kala and SPK004 suffered the highest weevil damage in the first rains. There was non-significant negative correlation ($r = -0.23$, $P = 0.65$; $r = -0.16$, $P = 0.17$) between yield and cumulative SPVD incidence in both seasons. Susceptible varieties still yielded highest and are capable of yielding higher if SPVD is checked using cultural control methods such as roguing,

planting clean vines and planting new fields at a distance (at least 100m).

Introduction

Sweetpotato is one of the major starchy staples for the majority of rural settings and the urban poor. Sweetpotato is the most widely cultivated and widespread food crop in Uganda and is grown as a major staple or as a supplement to banana, finger millet and cassava (Mwanga and Wanyera, 1988, Bashaasha *et al.*, 1995). The importance of sweetpotato as a food security and ready source of income to Ugandan farmers is increasing particularly in banana and cassava-based farming system due to increased pests and diseases (banana bacterial wilt, black Sigatoka, banana weevils and nematodes; and cassava mosaic disease). Even in areas where cereals are predominant (northern and eastern Uganda), sweetpotato serves as a buffer crop against famine and helps to supplement food supplies in the months preceding grain harvest. One of the major limiting biotic factor to increased sweetpotato productivity is sweetpotato virus disease (SPVD) (Carey *et al.*, 1999). SPVD has been ranked as the single most important disease constraint to sweetpotato production in the East African region and is the most important disease throughout Africa (Geddes, 1990). SPVD results from co-infection of sweetpotato plants with the aphid-borne *sweet potato feathery mottle virus* (SPFMV) (Family *Potyviridae*: Genus *Potyvirus*) and the

Bemisia tabaci-borne sweetpotato chlorotic stunt virus (SPCSV) (Family *Closteroviridae*: Genus *Crinivirus*) (Schaefer and Terry, 1976; Gibson *et al.*, 1998).

SPVD is reported to occur whenever sweetpotato is grown in the world, however, in Uganda, it is rare in eastern districts of Soroti, Tororo, and Busia but reaches damaging levels in central Uganda and in the southern districts of Masaka and Rakai (Aritua *et al.*, 1999). The prevalence of SPVD in these areas, coupled with farmers' limited knowledge about its cause and spread has exacerbated the problem.

Of recent there are efforts to combat vitamin A deficiency in children below 6 years by use of orange fleshed sweetpotato varieties. Use of orange-fleshed sweet potatoes (OFSP) rich in β -carotene, a precursor for vitamin A in the body, is being promoted as a food based approach to combat vitamin A deficiency in diets among vulnerable communities in Sub-Saharan Africa (Low *et al.*, 2001). A number of OFSP varieties have been identified and tested. However, sweetpotato virus disease (SPVD) is a major production constraint in Uganda and most of the introduced OFSP materials have succumbed to the viral damage. It is important that before the OFSP are passed to the farmers they are evaluated for desired attributes. This paper reports on experiments conducted to evaluate different promising OFSP varieties in Uganda.

Materials and Methods

The trial was done twice during the first and second seasons of 2002 at Namulonge Agricultural and Animal production Research Institute (NAARI). The clones included SPK004, Zapallo, Naspot5, Ejumula, and Kala. New Kawogo was included as a SPVD-resistant control. The trial was laid out in a randomized complete block design with six treatments replicated four times. Twelve vines were planted on a ridge of 5 m x 1 m with five ridges in a plot. At 1 month after planting (MAP) plants with SPVD symptoms were

rogued out since these would be cutting infections rather than vector introduced. SPVD data was collected on a monthly basis for a period of four months. Infected plants were counted per plot and recorded. Cumulative SPVD incidence was used in establishing correlation between SPVD and yield. At harvest (5 MAP), number of marketable roots, weight of marketable storage roots and total fresh weight was recorded. The total yield area harvested was computed from the 5x2 m (one ridge covering a meter). The weevil score was also recorded using a scale of 1-5 where 1= clean and 5= > 80% of surface area bored. Data analysis was done using SAS package to test for the difference in yield and resistance to SPVD.

Results and Discussion

Total fresh weight and marketable weight varied significantly among varieties (Table 1). The cultivar Ejumula had highest yield (17.8 t/ha) followed by Kala in the first season. In the second season the same varieties yielded highest. Zapallo and Naspot 5 were the least yielding. Kala and Zapallo suffered the highest weevil damage in first rains while Kala and SPK004 were the most damaged by weevils in the second season. New Kawogo had the least damage in both seasons. Cumulative numbers of infected plants with SPVD were highest in Naspot 5 and Ejumula in the first season while Zapallo and SPK004 had the highest SPVD incidence in the second season (Figure 1). However, the control New Kawogo registered lowest amount of disease in both seasons. There was generally less disease in second season compared with the first season. The difference in SPVD incidences in the two seasons could have been due to low rainfall in the first season (Table 2) which may have favoured whitefly population build up and hence more disease spread. This agrees with findings of Butler *et al.* (1983) that whiteflies are more active during warm temperatures and Fishpool *et al.* (1995) who showed rainfall to be negatively

Table 1: Marketable yield, weevil damage and fresh tuber weight of seven sweetpotato varieties grown at Namulonge, Uganda.

Entry	Marketable yield (t/ha)	Weevilscore	Fresh weight(t/ha)	Ranking for yield
First season				
Ejumula	13.3b	2.5ab	17.6bc	1
Kala	13.1b	3.0a	15.4bc	2
SPK004	11.6b	1.8ab	13.9c	3
Zapallo	4.2c	2.8a	6.0d	4
New Kawogo	1.6c	0.8cd	2.4d	5
Naspot 5	0.68c	1.0cd	1.9d	6
CV %	40.6	32.6	36.3	
Second season 2002				
Ejumula	11.7ab	1.3b	17.8a	1
Kala	8.7abc	2.5a	12.1abc	2
SPK004	8.9abc	2.0ab	11.1abcd	3
Naspot 5	1.3cde	1.5ab	1.8dc	4
Zapallo	0.5e	1.3b	1.6dc	5
New Kawogo	0.7de	1.0b	0.9d	6
CV %	83.7	51.1	83.5	

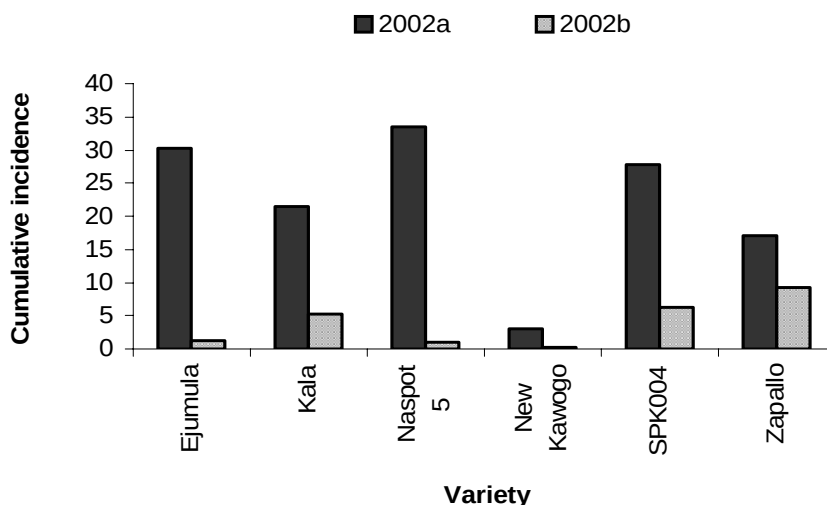


Figure 1: Cumulative number of plants with sweetpotato virus disease symptoms in the two seasons (2002a&b).

correlated with population size, possibly due to a reduction in oviposition.

There was a negative but non-significant correlation between cumulative SPVD incidence and yield ($r = -0.23$, $P = 0.65$; $r = -0.16$, $P = 0.17$) for the two seasons

respectively. The non significant correlation between SPVD and yield indicates that yield depended more on genetic potential of the clones considering that the resistant varieties still yielded less compared to susceptible ones. The yield potential of some of the

Table 2: Rainfall (mm) during the two seasons 2002a&b.

Month	Rainfall (mm)
May	2.80
June	2.58
July	0.58
August	2.05
September	5.65
October	7.87
November	7.36
December	6.39
January	2.60
February	2.60

varieties was low. Previous research by Aritua *et al.*, 2000 showed that varieties inoculated with SPVD yielded less compared to non-inoculated ones. This means that the susceptible varieties have the potential of yielding more if SPVD is checked. Therefore practising simple cultural control methods such as roguing, planting clean material may improve the yield of such clones.

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Farmer to farmer cassava varietal selection and breeding: The Domasi experience

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Abstract. In the year 2001 there was a national initiative to enhance the economic role of cassava in Malawi. Stakeholders ranging from farmers to entrepreneurs were invited to attend a symposium that provided impetus for nationally promoting the much-neglected cassava. For the resource poor-farmers this initiative could not have come at a more inappropriate time. There was a severe shortage of cassava planting material and some of the preferred varieties were extinct or at the verge of extinction due to pre-emptive harvesting and diseases.

For decades, farmers in Domasi had neglected their cassava due to the generous fertiliser subsidies that had up until the early nineties provided high yields of maize. The decline in fertiliser subsidies forced farmers in Domasi to turn to their “old trusted crop”, cassava. Unfortunately, cassava planting material was/is in short supply food shortage a recurrent problem further compounding the situation. Farmers started mobilising themselves into clubs in order to secure extra income or food production. Through the active involvement of the chiefs, local society and a Christian community based local NGO the farmers in Domasi have together with researchers and farmers from Mulanje introduced “new” local varieties to the area. The 17 varieties are currently under cassava club farmer field experimental condition. In this paper we present the process of forming cassava clubs and an exchange visit with

other cassava farmers in Mulanje district that has enabled the Domasi community to breed 17 locally adapted varieties within one year. The paper discusses mechanisms for improving the co-operation between resource-poor farmer’s and formal agricultural research and extension services.

Introduction

Cassava has become a major food staple of both rural and urban households in Malawi (Akoroda and Mwabumba, 2000). Even in good food crop production years, it forms the basic element in the food security of chronically food short households, an estimated one third of Malawi’s rural population (Benson, 2002). At times of food crisis, cassava takes over as the most important component in crop-based food security for almost all resource-poor families in Malawi (Moyo and Benesi, 1998). Moreover, output appears to be more robust in the face of biotic and abiotic stress and shock than other food crops (Mkumbira and Mahungu, 2003). The increase in overall cassava output has been more steady than maize over the last two decades (Haggblade and Zulu, 2003), a trend paralleling that estimated on the basis of aggregate statistics for Africa as a whole (IITA analysis for the period 1982- 2002, based on FAO production figures for cassava, sweet potato, and cereals).

Both men and women farmers produce, process and sell cassava (Chiwona-Karltun, 2001). However, they tend to have different variety preferences and roles, to work through gender-segregated networks, and to experience different social, agronomic and economic constraints in the production and sale of fresh and dried roots, and in opportunities to add value and generate income from product sales. Previous work (Chiwona-Karltun and Mkumbira, 1998; Mkumbira and Chiwona-Karltun, 2003) has shown that both male and female farmers are able to discriminate reliably among varieties on the basis of their morphological characteristics, and between bitter and cool/sweet varieties by the 'taste test' (Chiwona-Karltun and Brimer in press) and confirmed by molecular analysis.

However, in some areas farmers face major problems in maintaining the cultivation of preferred varieties because of poverty-related in-field thefts of fresh roots from a standing crop. Thieves appear to favour sweet varieties whose roots can be sold fresh without processing. Thieving reduces the diversity of the cultivars locally available and gives rise to chronic non-availability of planting stems. The shortage arises because (a) there are fewer plants left to take cuttings from; (b) taking cuttings from ratooned plants considerably reduces root yield, (c) the cuttings taken from the plants uprooted by thieves rarely survive through the dry season into the next planting season (unless there is irrigation). Only where the rainfall pattern allows continuous harvest and immediate re-planting are these chronic problems avoided (although thieving pressure remains a problem even in these areas, its knock-on impact on cassava biodiversity and food security is not so devastating). In order to protect household food security, farmers especially women often favour bitter over cool/sweet cultivars, even though the bitter varieties require considerable processing to remove the higher and potentially dangerously health-threatening levels of cyanogenic glucosides.

The aim of these studies (on going) is to design a participatory and efficient system of cassava cultivar introduction. The findings from these studies will facilitate in theory development, with respect to: innovation processes, thievery as a determining factor in cultivar selection and in comprehending cassava-based livelihood and gender issues.

Material and Methods

The Context and Background The activity described here is taking place in 17 villages in Malosa Extension Planning Area (EPA), Naisi Section, and Naming'azi Ward. Domasi is the modest commercial centre at the heart of the Ward. It straddles the main Zomba -Lilongwe highway in southern Malawi, toward the border with Mozambique. There is a small roadside market and a large periodic market some 6-km along the highway to the south leading to Blantyre. Zomba town, some 12 km towards the south, offers a range of modern commercial and administrative services, as well as the amenities associated with Chancellor College, one of Malawi's most prestigious universities. The national Teacher Training College lies within Domasi itself and there is an extended middle class residential area to one side of the highway.

The original research design. The original research design envisaged materials flowing from the formal system to a selected village, in support of local breeding processes, which we assumed on the basis of previous research (Chiwona-Karltun, 2001) were occurring through varietal selection and exchange of materials between villages.

We further assumed that there was some necessary relation between farmers' selection preferences and market demand. We intended to track the existing flow of materials, and those introduced through both the formal and informal systems, by means of molecular marker characterisation (Fregene and Suarez, 2003) in farmer-preferred varieties, and subsequent recovery of cassava materials

from designated markets, in order to track the penetration of these preferred materials.

The study design has been modified considerably in the light of facts on the ground. The most important of these are fundamental to any long-term sustainability of cassava breeding: The impact of HIV/Aids. Our data show that HIV/AIDS is profoundly altering the following variables:

Leadership and entrepreneurial capacity at the local level. This is evident in the decimation of the chiefs; the incidence of households headed by women alone and by children; the decline of local market demand, and the marked shifts in cropping systems (de Waal and Whiteside, 2003).

Governance. Those dependent on government salaries are demanding that the pensionable age be reduced to 35 years, so that dependants left behind are able to enjoy some support. Around a third of all Malawians are thought to be infected. With so much time off taken for attending funerals, services are further badly hit; the loss of efficiency is spiralling into increasing indebtedness and further loss of capacity.

Economic relations. Local economies are falling back on former patterns of exchange relations and social networking in order to survive. The efficiency and effectiveness of public services is reduced, to the point where many official bodies are no longer capable of delivering any service.

This spiral into long term decline has many negative aspects. One of the most serious for the research question is the chronic weakness of the formal agricultural research system. The research stations most relevant for cassava breeding, are unable to supply sufficient (and at times, any) cassava cuttings, they have inadequate on-station multiplication capacity, no security, virtually no transport, and virtually no financial resources. The research staff is languishing through sickness, premature death, lack of trained scientific supervision and research project funding, and

inadequate or broken equipment, or ill-supplied facilities. In short, the formal system is not able consistently to supply new cultivars, let alone sustain close and reliable interaction with farmers in a participatory plant breeding (PPB) relationship.

Results

Adaptations of the research design. First, the project provided transport, and facilitated the contact, between farmers in Domasi and farmers further south close to the Mozambique border, where there are better soils, good rains, and a wider variety of cultivars, where the researchers had had previous research contacts. Farmers' visual characterisations were recorded, and sets of selected varieties were tagged. Each Cassava Club received their preferred set, to plant in their own Farmer Trials. Individual farmers also took materials for planting in their own fields. One complete set of all accessions in the farmers' trials was planted out in a reserve plot donated by a missionary-run Farmer Training Centre, Namingazi Farm Centre, close to Domasi. The trial and reserve accessions subsequently were described morphologically by a trained technician.

Farmer exchange visits. Subsequently, the farmers from Mulanje, the south, visited the Domasi cassava clubs and made their own selections, they only selected one variety due to lack of cassava as well as participating in a product development session run by a local entrepreneur. Later on, Domasi farmers visited and made selections from the accessions managed by the regional cassava network, SARRNET. The accessions included varieties grown for leaf quality and harvesting and some farmers chose to take a number of these – for them, it was a novel idea that you might choose to specialise in leaf harvesting and sale. Although leaves are consumed, they are harvested sporadically and only for home consumption. Again, the farmers', and this time also the scientists', selection criteria were recorded, and the accessions were tagged and

those entered into the reserve plot and Club trials were later morphologically described.

Varietal assessment by Domasi Farmers of acquired cultivars. In September 2003, farmer assessments made at harvesting from the reserve plot and their own trials were recorded, through to cooking quality and taste assessments (forthcoming). On the basis of the results of these exercises, it was decided that some should be put back into trial, some planted for multiplication, and some sold as fresh roots in order to generate funds for the Clubs. The remaining roots and planting materials were shared out among Club members, based on a 'fair' allocation devised among the farmers themselves. Because of the need to be able to determine the distinctiveness of varieties of roots collected, at a later date, in markets and non-participating farmers' fields, work also has been initiated to carry out DNA analysis from both the leaves and roots. It is worth noting that none of the farmers' trials, or the reserve plot, has been robbed; though the risk is always there.

Market Research and product Development.

The original research design has also been modified with respect to the product development and marketing objectives. A small, farmer-selected, market research team has participated in the investigation of the conditions in which fresh roots and processed products are sold in town and periodic markets and cassava trading. They have also actively promoted a range of cassava products in various venues. A number of farming families are beginning to take up some of these ideas.

Discussion and Conclusion

The question naturally arises: where is the public research system in what is evolving. Researchers at Bvumbwe, Chitedze, Makoka Research Station, and SARRNET have provided invaluable advice, and have smoothed the way through numerous administrative and operational problems. They have willingly engaged in cost sharing,

whenever their own funds have permitted, and given generously of their time whenever transport was available. SARRNET has provided access to the farmers of their own accessions. However, it has to be faced that what in particular Bvumbwe, Chitedze and Makoka Agricultural Research Stations can offer is at best an "unreliable" and limited back-up; they are simply not in a position to act effectively towards creating an enduring, and institutionalised, participatory breeding system in terms of human, technical and financial resources. Malawi NARS, though willing and able, are not in a position to execute decentralised cassava breeding to address cassavas' specificity due to genotype by environment interactions as is recommended by the international agricultural research centres (Dixon and Bandyopadhyay, 2003). The most feasible solution for the time being, for optimising the cultivation of cassava as a food security crop as well as for commercial purposes is by expanded participatory varietal selection (PVS) in the absence of policy and investment reforms (Rosegrant and Cline, 2003).

Although the process described appears to offer promise and to be "the right research" (Lightfoot and Scheurmeier, 2003) it would be imprudent to over-value what has occurred. There are tensions that will have to be confronted and overcome. This has to do with the inequalities that inevitably exist within any community: who is benefiting and who is left out? The drivers of the activity are the somewhat better off farmers, the younger chiefs, and the somewhat more educated, although club membership includes the socially vulnerable and the HIV/AIDS affected. So far the group decision-making process has satisfied the need to spread opportunities from the leading actors to the core group of cassava club members and beyond. This is largely in the form of access to farmer-preferred planting stems, and sharing the experience of farmer-led cassava development, through the Cassava Farmers' Fair. The project has been up and running for two years and this is a short time for any

meaningful conclusions to be drawn for a crop that is vegetatively propagated and for communities whose social fabric is constantly tested by the vagaries of nature.

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Land preparation for increased sweetpotato production in Ghana

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Abstract. Sweetpotato in southern Ghana is planted mainly on manually constructed mounds. A land preparation study was initiated on 16 farmers fields in 2001, and advanced to a total of 19 demonstration plots in 2002 and 2003. The objectives were to compare the agronomic feasibility and farmers' perception of manual and mechanized construction of, and management of sweetpotato on ridges with farmers' practices. Planting on ridges resulted in a significant ($P=0.05$) increase (38%) in sweetpotato tuber yield over farmers' practice of planting on mounds under favourable rainfall, as a result of increased number of tubers and crop growth per unit area. Planting on flat land resulted in drastic yield reductions of 28% and 59% from ridges in the major and minor seasons respectively. Farmers' perception of overall ease of manual management was similar for ridges and mounds. However, differences were reported in various aspects of management, with construction being easier on mounds (score=2.6) than on ridges (score=3.3), weeding easier on ridges (score=2.0) than on mounds(2.6), and harvesting easier on mounds (score=1.3) than on ridges(score=1.7) Mechanized ridging, using tractor mounted ridgers was demonstrated on farmers' fields in 2003, and was shown to be much easier and in some areas less expensive to construct than mounding and manual ridging. Ridging has the potential to increase national sweetpotato production through increased yield per unit area, removal of drudgery associated with land preparation, and increase in the acreage under sweetpotato production in Ghana.

Introduction

Among the root crops, sweetpotato (*Ipomoea batatas*) production in Ghana ranks fourth after cassava, yam and cocoyam. It was reported that an estimated 78,000 households were engaged in its production in 1999 with annual value of 18.2 billion cedis (Ghana Statistical Service, 2000). Current production estimate is expected to increase due to recent research and extension interventions in sweetpotato production in Ghana.

Major constraints in sweetpotato production in southern Ghana (Brong Ahafo, Ashanti, Eastern, greater Accra, Central and Volta Regions) are low plant population density due to widely spaced mounds, variable planting dates, no organic or inorganic fertilizer application, and lack of market in the Ashanti and Brong-Ahafo Regions (Dankyi *et al.*, 1997; and Anchirina *et al.*, 1997) and non availability of planting material.

Land preparation for sweetpotato cultivation consists of bush burning or tractor ploughing after which hoes and sometimes mattocks are used to prepare mounds. Ridges are sometimes made with hoes and in certain cases on ploughed land; sweetpotato is planted directly on the flat ground without mounds or ridges (Dankyi *et al.*, 1997; and Anchirina *et al.*, 1997). Ridges are also constructed with bullock ploughs in the Upper East region. In the Central and Volta Regions of the country, sweetpotatoes are planted predominantly on irregularly and widely spaced mounds resulting in low plant populations. The objectives of the study are

1) to determine the agronomic feasibility and farmers' perception of the different sweetpotato land preparation methods 2) quantify yield response to planting on ridge, mound and flat, and 3) involve farmers in the selection of the best land preparation method for sweetpotato production.

Materials and Methods

A sweetpotato land preparation study was initiated in 2001 on farmers' fields in the Central and Volta Regions of Ghana. Ten sweetpotato farmers were selected for major season (April/May) plantings and 1 for mid season (July) and 6 for minor season (August/September) plantings in the Central and Volta Regions of Ghana. The agroecologies of the sites were coastal and forest-savanna transition zones. A collaborating farmer either ploughed or slashed and burned the fields after which three plots each 8m wide and 10m long were demarcated and randomly assigned 3 land preparation treatments: 1. ridges 2.mounds and 3. flat with mounds as farmers' practice. Flat treatment consisted of planting directly on the ground without raising a seed bed. The experimental design was randomized complete block with farmers as replications for a total of 10 replications in the major season and 6 replications in the minor season. One site was planted at mid-season in July. Sweetpotato variety 'Sauti', an improved 4 month yellow skinned and yellow fleshed variety was used in 13 sites. Existing 'local' varieties were used at 3 other sites due to lack of planting material. Data were collected on seed bed size, ease or difficulty of management by farmer, plant biomass, tuber yield, tuber characteristics, and insect damage. At harvest in 2001, field days were organized for 5-25 farmers per site. Data were analyzed statistically using SAS (SAS Inst. 1988), and variables subjected to regular analysis of variance. In major season 2002, 9 demonstration plots of ridges as a land preparation method for sweetpotato production were established in the Central and Volta Regions using improved variety

'Sauti' in 7 locations and local red variety in 2 locations. Each plot was ¼ acre in size and 2 field days were organised per plot during the vegetative stage and at harvest. In 2003, ten ¼ acre demonstration fields were established with two sites mechanically ridged with tractor mounted ridgers.

Results and Discussion

Management and crop growth. In the major season overall ease or difficulty of sweetpotato management on ridges was found to be similar to mounds. They were both ranked between easy and difficult (Table 1). Further discussions with the farmers revealed that there was the need to break down management into land preparation, weeding and harvesting which was done in the minor season. Results indicated that (Table 2) land preparation by ridging which is new to farmers in the area of study was found to be difficult compared to mounding which was ranked between difficult and easy. Preparing flat land was obviously easy. Although it was observed that farmers in Volta Region constructed taller mounds than in Central region, on a farmer's field, ridges were constructed as high as mounds (Table 2). Weeding was found to be easy on ridges, between difficult and easy on mounds and difficult on flat. Better plant biomass production (Table 2) and ground cover by vines on ridges than the irregularly spaced mounds apparently lead to better weed suppression. Difficulty in weeding on flat could be due to the poor plant stand and reduced plant growth resulting in the observed greater weed infestation. Flowering (Table 2) occurred only in the local sweetpotato varieties. Harvesting was between easy and very easy on ridges, very easy on mounds and difficult on the flat. Overall management was easy on ridges and mounds and difficult on flat due to the difficulty of weeding and harvesting on flat. The issue of difficulty of manual preparation of ridges was mentioned mostly by farmers in the Central region, who it was observed did not plough their fields,

Table 1: Farmer's perceptions of sweetpotato management under different land preparation methods, 2001.

Land preparation method	Time for land preparation (hrs/ha)	Ease of management			Mean	
		Seed bed construction	Weeding	Harvesting	Major season	Minor season
	Major season	Minor season	Minor season	Minor season	Major season	Minor season
Ridge	149	3.3	2.0	1.7	2.3	2.3
Mound	142	2.6	2.6	1.3	2.7	2.2
Flat	0	1.9	3.2	3.0	1.4	2.7
SED _(0.05)	30.3	0.32	0.38	0.33	0.29	-

*1=very easy; 2=easy; 3= difficult; 4= very difficult 5= too difficult.

Table 2: Sweetpotato growth under different land preparation methods. Central and Volta Regions, 2001.

Land preparation	Seed bed size (cm)		Days to 50% flowering		Fresh vine weight per plant (g)		Total fresh vine weight (t/ha)
	Minor season		Major season	Minor season	Major season	Minor season	Minor season
Method	Height	Width	Major season	Minor season	Major season	Minor season	Minor season
Ridge	46	85	61	74	668	418	15.5
Mound (FP)	45	84	63	76	595	413	10.4
Flat	-	-	62	77	494	363	11.1
SED (0.05)	3.5	3.4	0.8	1.0	80	56	-

and women farmers. Ridging unlike mounding, is amenable to mechanization and has been described as an improved land preparation method, which affords better control of plant population than mounds and facilitates other field operations in yam production (Orkwor and Asadu, 1998). At the field day, demonstrating ridging with tractor mounted ridger, mechanized ridging was found to be cheaper than mounding. Even in localities where ploughing is most expensive, mechanized ridging did not add any extra cost compared to mounding. Mechanized ridging with tractor mounted ridgers could be provided as a commercial service, as is currently the case with ploughing and

harrowing for majority of farmers in Ghana. This will eliminate the drudgery associated with land preparation; facilitate the expansion of farm sizes and increase sweetpotato production.

Yield and physical characteristics of tubers.

Ridging resulted in a significant ($P=0.05$) increase (38%) in sweetpotato tuber yield over farmers' practice of mounding in major season (Fig. 1) and yielded similarly to mounds in the minor season. Tuber yields were significantly lower for sweetpotato planted on flat fields. Average rainfall from three of the locations during the 4 months growing period was 500mm in the major season and

207mm in the minor season. Yields were lower in the minor season. However, the higher yield advantage of ridges in the major season over other land preparation was not evident in the minor season. Apparently drought stress was a contributory factor to the observed trend, resulting in the bridging of the gap between

number of tubers on the ridges and mounds (Figure1). The lower plant population density on mounds was compensated for by the bigger tuber sizes in the minor season as shown by the tuber weight per plant. In the major season, this compensation was not achieved and tuber size from ridges and

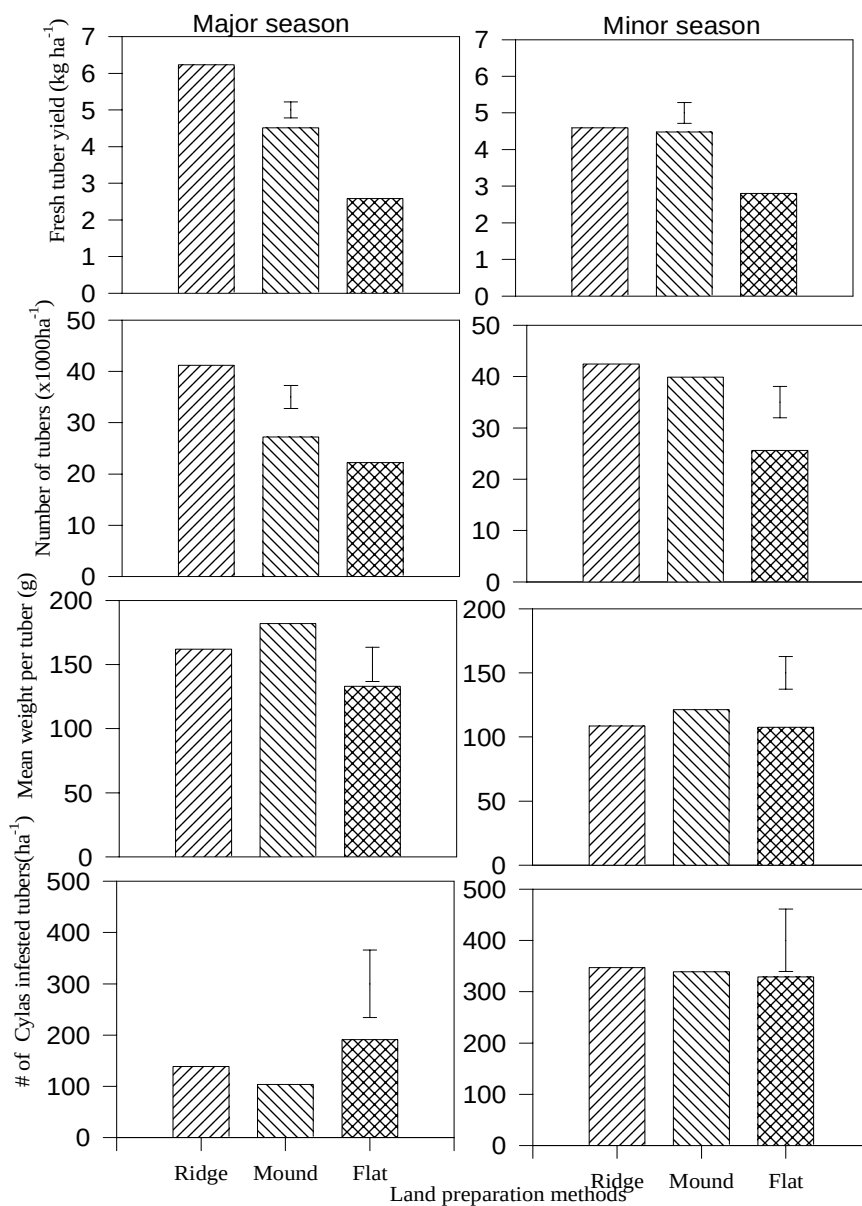


Figure 1: Effect of land preparation method on yield and tuber characteristics of sweetpotato. Vertical bars represent 2 x Standard Error.

mounds were not statistically different ($P \leq 0.05$), resulting in higher yields on ridges. At one site, Afife, the trial was planted with a very high yielding local white skinned are fleshed variety 'Yevuvi' in July. This variety yielded 20,635 kg ha⁻¹ on ridges, 21,062 kg ha⁻¹ on mounds and 17,323 kg ha⁻¹ on flats. There is the need to include such already existing high yielding materials in current breeding programs in the country.

Tuber shape was distinctly different on ridges and mounds, with slender elliptical tubers obtained on ridges and oblong shaped tubers on mounds. Width and height of ridges and mounds were similar. There was no correlation between mound height or width and tuber yield.

Insect damage to tubers was negligible in the major season, and increased in the minor season, with more than doubling of number of tubers with damage by weevils (*Cylas* spp.) (Fig. 1). *Cylas* damage was not affected by land preparation method in either the major or minor season. It was observed that exposed tubers were predisposed to *Cylas* damage; therefore, reridging during the first weeding and covering up exposed tubers could

minimize the damage. The use of a 5-1 plastic jerry can traps with 1g litre water of a detergent (Omo) solution placed 15cm above the canopy has been recommended in the control of African *Cylas* species of sweetpotato in Uganda (Smit *et al.*, 1997). Millipede damage was observed in one location in the Volta region in the minor season, with higher infestation on ridges (23%) than on mounds (9%) and flat (19%). Apparently, this was due to the continuity and ease of movement of the millipede through the seed bed offered by ridges. Quality of tubers in terms of appearance was lowered by millipede damage. In the absence of recommended chemical control, mounding for sweetpotato production would be a better option in areas endemic to millipede damage.

During field days in 2002, 197 people comprising of 129 male and 53 female farmers and 17 Agricultural Extension staff of the Ministry of Food and Agriculture were exposed to ridging as a land preparation method, sweetpotato production in general, and the improved variety 'Sauti' in the Central and Volta Regions. At harvest field days,

Table 3: Partial budget analysis for planting sweetpotato on ridges in the Central and Volta Regions of Ghana. Major Season 2002.

	Central region(slash and burn)	Volta region(ploughed)
Yield (kg ha ⁻¹)	7 085	6 720
Adjusted yield (kg ha ⁻¹)	5 668	5 376
Price /50 kg bag (cedis ¢)	65 000	32 000
Gross field benefits	3 684 200	3 440 640
Cost per hectare (cedis, ¢)\$1 = ¢7000 (2002)		
Slashing	27 000	27 000
Ploughing/ hoeing	45 000	375 000
Ridging	750 000	280 000
Planting	150 000	150 000
1 st weeding	270 000	300 000
2 nd weeding	135 000	100 000
Harvesting	180 000	300 000
Carting	170 040	268 800
Total cost that vary	2 375 040	2 043 800
Net benefits (in cedis)	1 309 160	1 396 840
Net benefit (US\$)	187	200

farmers were given some vines to plant on their own farms.

Economic benefits. Partial budget analysis (Table 3) from the demonstration plots indicates that sweetpotato production is a profitable business with net benefits of €1.3 million/ha (US\$187) and €1.4 (US\$200) million/ha per season in the Central and Volta Regions respectively under ridging. It is apparent that net benefits could be further increased if higher price is obtained through improved marketing of the crop especially in the Volta region and lowering of cost of ridging in the Central region through mechanization.

Conclusion

Planting sweetpotato on ridges resulted in a significant ($P \leq 0.05$) increase (38%) in yield over the farmer's practice of planting on mounds in the major season (April/May), with no significant increase in the minor season (August/September) plantings. Adoption of ridging as a land preparation method has the potential to increase sweetpotato production in Ghana through increased yield per unit area and increased total area under sweetpotato production through expansion of farm sizes.

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Effect of co-formulated fungicides on late blight management in seed and ware potatoes

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Abstract. Late blight caused by *Phytophthora infestans* (Mont.) de Bary is the most important potato disease in Cameroon. Three co-formulated fungicides (Anteor Super, Galben Plus and Ridomil Plus) were evaluated in 2000 for efficacy in suppressing late blight development in seed and ware potato fields. The trial was conducted at Upper-Farm, Bambui (2000 masl). A randomised complete block design was used with four replicates. Three potato varieties (Desirée, Cipira and Tubira) were treated twice with the fungicides at manufacturers' recommended rates. The first treatments were applied at the appearance of the first late blight symptoms (35 DAP) and the second sprays were applied 21 days later. Control plots were not sprayed. Late blight severity varied with fungicide treatment and variety. Low disease intensities and high seed and ware potato yields were obtained in sprayed plots. The highest yields and net returns were obtained generally in plots treated with Ridomil Plus, followed by Galben Plus. Tuber yields and net returns from fungicidal control varied with fungicidal treatments and variety. Ridomil Plus was the most profitable fungicide, while Anteor Super was the least. Net returns to Ridomil Plus applications varied from US\$ 1,649.27 to 6,949.27/ha for seed potatoes and US\$ 1,400.70 to 2,494.98/ha for ware potatoes. Results show that the co-formulated fungicides used have a potential to suppress potato late blight severity and increase seed and ware potato yields and consequently net farm incomes.

Introduction

Potato (*Solanum tuberosum* L.) plays an important socio-economic role because of its high productivity and nutritional quality (Hakiza, 1999). It is currently the fourth largest food provider in the world, after cereal crops like maize, rice and wheat. World potato production in 2002 was estimated at 308 million metric tons produced on 19 million hectares of land (FAOSTAT, 2003). Africa accounts for only 4% of this production on 6% of total world hectareage (FAOSTAT, 2003). Of the 34 African potato producing countries yield in, 22 is less than 10 t/ha and this is attributed to biotic and abiotic constraints (Hakiza, 1999). The most important biotic constraint of potato production in the world is late blight, caused by *Phytophthora infestans* (Mont.) de Bary. It limits the potential of the crop in fulfilling its role as a global food provider.

Five promising potato varieties were released in Cameroon in 1992 (Martin *et al.*, 1995) and about 37 metric tons of sprouted basic seed tubers were distributed to more than 735 farmers (Deffo *et al.*, 1998). Two of the five varieties, Cipira (CIP 381381.13) and Tubira (CIP 381406.6), were widely adopted by potato farmers (Deffo *et al.*, 2003) for their high productivity and resistance to late blight. However, the level of late blight resistance in both varieties has been decreasing in recent years (Demo *et al.*, 1999; Fontem and Tsopmbeng, 2003; Njualement *et al.*, 2001). Consequently, farmers started using

fungicides intensively and indiscriminately to control this disease (Fontem and Tsopmbeng, 2003; Fontem *et al.*, 1998). Studies conducted in the western highland agro-ecological zone of Cameroon revealed that two applications of a co-formulated fungicide, Ridomil Plus (12 % metalaxyl + 60 % copper oxide), at a relatively low rate are more effective in late blight management than six weekly applications of contact fungicides, such as maneb, mancozeb or cupric hydroxide (Fontem and Aighewi, 1991; 1993). Further studies also indicated that two applications of Ridomil MZ (12 % metalaxyl + 60 % mancozeb) or Ridomil Plus were effective in potato late blight management (Fontem, 1995a,b; 2001; Fontem *et al.*, 2001a). Samoucha and Cohen (1989) also reported that co-formulations of systemic and contact fungicides are more effective in reducing potato late blight severity than the individual fungicide components.

The main purpose of this study was to assess the effects of the applications of co-formulated fungicides, Anteor Super, Galben Plus and Ridomil Plus, on late blight severity and yield of seed and ware potatoes.

Materials and Methods

Trial site. Two field experiments were conducted at Upper Farm (10.04°E, 6.07°N, 2000 masl) in the North West province of Cameroon during May to August 2000. The site has a yearly rainfall of 1760 mm, a mean temperature of 12.3 °C and a total sunshine of about 1900 h. The major soil types are ferrous soils on slopes and hydromorphic soils in valleys.

Experimental design and cultural practices. The experimental design used for each trial was a 3 x 4 factorial involving three potato varieties (Desirée, Cipira and Tubira) and four fungicide treatments (Anteor Super, Galben Plus, Ridomil Plus and an unsprayed control) in four randomised complete blocks. A 2-m potato free zone separated experimental units from each other to avoid possible interactions.

Experimental units consisted of four ridges of 3m long. Multiple sprouted tubers, each 50 g, of two late blight tolerant potato varieties (Cipira and Tubira) and a susceptible variety (Desirée) were planted on 6 May 2000. Plants were spaced 1.0 x 0.3 m, giving a plant density of 33,333 plants/ha. A fertiliser formulation of 60-180-100 of N, P₂O₅ and K₂O from urea, triple super phosphate and potassium nitrate was applied at 720 kg/ha during planting. Urea was applied at 130 kg/ha during earthing up (36 days after planting, DAP). Plots were weeded during second earthing up at 50 DAP.

Fungicide protection was applied using a Solo knapsack sprayer (Solo Kleinmotoren GmbH, Sindelfingen, Germany) that delivers about 800 L/ha at a maximum pressure of 4 kg/cm² using a single flat fan nozzle. Three fungicides were applied at the first appearance of late blight symptoms (35 DAP). Plots were sprayed twice with Anteor Super, Galben Plus and Ridomil plus or left unsprayed (control). The first treatment was applied at first foliar symptoms; while the second was applied 21 days later (56 DAP). All treatments were applied at manufacturers' recommended rates (Table 1). The trial was carried out under nature inoculum. Late blight severity (proportion of leaf area diseased) was assessed at weekly intervals on five randomly selected plants in the centre rows of each plot using a modified Horsfall-Barratt (Berger, 1980) rating scale. Disease assessment were made weekly from the time the first foliar late blight symptoms were observed. A total of nine and eight assessments were made for ware potato and seed potato plots respectively. The Horsfall-Barratt severity ratings were converted to disease proportions with the conversion tables of Redman *et al.* (1967). Values for standardised area under disease-progress curves (SAUDPC) were calculated from the severity data according to the formula used by Campbell and Madden (1990).

Tubers in each inner rows of each plot were hand-harvested at 84 DAP for the seed production trial and 104 DAP for the ware potato production trial. Seed tubers were sorted and graded into grades I (tuber size ≤

Table 1: Fungicide treatments used for late blight protection in potato.

Fungicide	Formulation	Active ingredients	Rate (kg/ha)
Anteor Super	49.6 WP	9.6% cymoxanil + 40% copper metal	3.0
Galben Plus	78 WP	18% benalaxyl + 60 % copper metal	2.5
Ridomil plus	72 WP	12% metalaxyl + 60% copper oxide	2.5

25 mm diameter), II (tuber size 25 to 55 mm) and III (tuber size ≥ 55 mm). Ware tubers were also sorted but after discarding diseased tubers, healthy ones were graded into marketable (tuber weight ≥ 20 g) and unmarketable (tuber weight < 20 g) tubers. For both potato types, tubers in each grade were counted and weighed. All tuber yields were expressed in t/ha of fresh weight.

Economic Appraisal of Fungicidal Control.

Economic analyses were computed for costs and returns to the different fungicidal treatments for both seed and ware crops as suggested by Horton (1982). The same cost items were considered for different cultural techniques carried out on the different fungicide treatment plots. What differed between the treatments was the cost of the fungicides used and their application. During a storage period of about seven months prior to planting, seed yields registered a weight loss of about 30% for grade II tubers and 60% for grade I tubers. Consequently, a seed weight of 70% or 40% of the initial seed weight was considered for both seed categories, respectively.

Total returns were the value of the seed or ware potato yield obtained in each treatment. A unit farm gate price of \$ 1.43/kg for grade I tubers, \$ 0.71/kg for grade II tubers and \$ 0.14/kg for grade III tubers was applied on seed yields to estimate the total returns. For ware potato returns, a unit price of \$ 0.14/kg was used for marketable tubers and \$ 0.03/kg for unmarketable tubers. The cost of each fungicide and its application was also assessed. The cost of applying the fungicide with a knapsack sprayer was estimated at US\$ 15/ha (US\$ 5.0/manday x 3 mandays/ha).

Returns for the tuber grades were obtained by multiplying the yield of each fungicidal treatment by its farm gate price. The net return (NR) for each fungicide treatment was obtained by deducting total cost (TC) of fungicide protection from total return (TR), $NR = TR - TC$. Increase in net returns due to fungicide application in seed or ware potato farms was assessed by deducting the net return from the unsprayed plot from that obtained in sprayed plots to determine the most economically efficient fungicide spray regime.

Data analysis. Disease and yield data were analysed by analysis of variance (ANOVA) using an MSTAT-C statistical package (Michigan State University) and their means separated using the Duncan multiple range test at $p = 0.05$. Correlation analyses were performed between the SAUDPC and yield variables of seed and ware potatoes to determine the relationship between late blight severity and yield components. Economic analyses were performed for fungicidal control of potato late blight for both seed and ware potatoes. The fungicide treatment that yielded the highest increase in net return for seed or ware potato production was generally recommended for use by farmers.

Results

Late blight severity. The first detection of late blight symptoms was recorded four weeks after planting on the lower leaf canopies of the three varieties and the severity progressed towards the upper leaf canopies. Disease progress into the upper leaf canopies was faster on Desiree than on Cipira or Tubira.

An analysis of variance revealed highly significant ($p < 0.001$) varietal and fungicide effects on standardised area under disease-progress curve (SAUDPC) for both seed and ware potato fields. However, variety x fungicide interaction effects on disease severity were not significant ($p > 0.05$) for both fields. Late blight was generally less severe in the seed potato field than in the ware potato field most likely because the former was harvested earlier than the latter.

Desirée was more susceptible to late blight than Cipira and Tubira in both seed and ware potato fields. The resistance level of Cipira and Tubira to late blight was not significantly different in the seed potato field (Table 2). Late blight was most severe in unsprayed control plots in both fields. Within the sprayed plots, SAUDPC values were lower on plots treated with Ridomil Plus than on those treated with Galben Plus or Anteor Super (Table 2).

Effect of fungicide treatments on seed yield and yield components. Potato yields included total and marketable or graded yields, while yield components were tuber number and tuber weight. An analysis of variance for

Table 2: Main effects of varieties and fungicides on standardised area under disease progress curve (SAUDPC) in seed and ware potato fields.

Main effects	Seed potatoes	Ware potatoes
Varieties		
Désirée	0.214 a*	0.315 a
Cipira	0.157 b	0.234 b
Tubira	0.139 b	0.201 c
Fungicides		
Unsprayed Control	0.230 a	0.324 a
Anteor Super	0.167 b	0.257 b
Galben Plus	0.161 b	0.240 b
Ridomil Plus	0.123 c	0.180 c

*Means in a column for the same main effect followed by the same letters are not significantly different according to Duncan's multiple range test ($p = 0.05$).

potato seed tuber yield data revealed significant ($p \leq 0.01$) variety x fungicide interactions for total yield, yield of grade II tubers and tuber number, while the interactions were not significant ($p > 0.05$) for tuber weight and grades I and III seed tuber yields (Table 3). A significant increase in tuber weight was recorded in fungicide sprayed plots.

Total seed yield of the three varieties increased significantly with all fungicide treatments. Generally, the highest total yields for the three varieties were obtained in plots exposed to Ridomil Plus sprays and the lowest one on the unsprayed control plot (Table 4). Except for Tubira where Ridomil Plus-treated plants had the highest grade II yields, fungicide treatments did not generally affect the yields of this size of tubers. Conversely, except for Désirée where fungicide treatment did not significantly affect tuber number, this variable increased significantly with fungicide treatments for Cipira and Tubira (Table 4).

Effects of fungicides on ware potato yield and yield components. The effects of fungicide treatments on ware potato yields are presented in Table 5. Unlike in seed potatoes, significant variety x fungicide interaction effects were noted for all the yield variables of ware potatoes. Consequently, the effects of the fungicide treatments differed according to the variety used. The highest total and marketable yields of each variety were recorded in Ridomil Plus sprayed plots. Except for Tubira where Galben Plus treated plots out-yielded Anteor Super-sprayed plots, Désirée and Cipira plots treated with both fungicides had significantly similar yields, tuber weight and tuber number (Table 5).

Correlations between late blight severity and potato yields. SAUDPC values were negatively correlated with seed and ware potato yields and yield components (Table 6). For seed potatoes, the correlations were highly significant ($p < 0.001$) for tuber number, grade II tuber yields and total yields, and significant ($p \leq 0.05$) for grade III tuber yields, while correlations with seed tuber weight and

grade I tuber yields were not significant. Similarly, for ware potatoes, highly negative ($p < 0.001$) correlations were obtained between SAUDPC and tuber number, marketable yields or total yields, and significant ($p \leq 0.05$) for tuber weight (Table 6).

Economic analysis of fungicide control of potato late blight. The costs of the fungicides needed to protect a hectare of seed and ware potatoes against late blight are shown in Table 7. Three mandays were needed to spray a hectare of seed or ware potato farm with each

Table 3: Main effects of varieties and fungicides on seed tuber weight and yield of grades I and III tubers.

Treatments	Tuber weight (g)	Seed tuber yield (t/ha)	
		Grade I	Grade III
Varieties			
Désirée	43.0 a*	0.29 b	1.81 b
Cipira	30.9 b	0.86 a	3.22 a
Tubira	36.4 ab	0.43 b	1.11 b
Fungicides			
Unsprayed Control	29.0 c	0.63 a	0.60 c
Anteor Super	37.8 b	0.49 a	1.95 bc
Galben Plus	35.5 b	0.67 a	2.03 b
Ridomil Plus	44.7 a	0.33 a	3.60 a

*Means for the same main effect followed by the same letters in each column are not significantly different according to Duncan's multiple range test ($p = 0.05$). Tuber size was ≤ 25 mm in diameter for grade I and ≥ 55 mm for grade III.

Table 4: Effect of fungicide protection on seed potato yields at Upper Farm, Cameroon.

Variety	Fungicide	Total seed yield	Grade II tuber yield (t/ha)	Tuber number
Desirée	Unsprayed Control	12.9 b	11.8 a	9.1 a
	Anteor Sup.	13.4 b	11.6 a	8.0 a
	Galben Plus	15.1 ab	13.4 a	9.2 a
	Ridomil Plus	18.3 a	14.5 a	7.4 a
Cipira	Unsprayed Control	13.7 b	12.1 a	12.2 b
	Anteor Sup.	18.4 a	14.2 a	13.9 ab
	Galben Plus	23.1 a	17.9 a	14.5 ab
	Ridomil Plus	22.9 a	17.8 a	15.5 a
Tubira	Unsprayed Control	13.3 c	12.4 c	10.4 c
	Anteor Sup.	20.5 b	19.4 ab	13.6 b
	Galben Plus	18.0 bc	16.8 b	13.6 b
	Ridomil Plus	28.6 a	25.7 a	17.5 a

*Means in a column for each variety followed by the same letters are not significantly different according to Duncan's multiple range test ($p = 0.05$). Tuber size was 25 – 55 mm in diameter for grade II.

fungicide. Ridomil Plus was the most costly fungicide, while Anteor Super was the least. Seed tubers are usually stored for up to 7 months under diffuse light conditions before sale because they would have to pass through a dormancy period and develop sprouts before planting. Ware potatoes and grade III (large) seed tubers are sold directly after harvest and no weight loss is considered for them. Grade III seed tubers were sold at harvest at \$ 0.14/kg as ware potatoes since large tubers are less efficient in converting their unit weight

in tuber yield than smaller ones. However, seed grades I and II were sold at \$ 1.43/kg and \$ 0.71/kg, respectively. Ware potatoes were graded into marketable (tuber wt ≥ 20 g) and unmarketable (tuber wt < 20 g) tubers and sold respectively at \$ 0.14/kg and \$ 0.03/kg.

The returns to fungicide treatments in seed potatoes are presented in Table 8. The economic benefits of fungicide application depended on the variety planted. Net returns in sprayed plots varied from \$ 6,142.85 to 13,363.56/ha. Ridomil Plus was the most

Table 5: Effect of fungicide protection on ware potato yields at Upper Farm, Cameroon.

Variety	Fungicide	Total yield (t/ha)	Marketable yield (t/ha)	Tuber weight (g)	Tuber number
Désirée	Unsprayed control	13.6 c*	12.9 b	35.9 b	11.6 a
	Anteor Super	16.4 b	14.5 b	39.1 b	12.2 a
	Galben Plus	17.2 b	15.7 b	44.2 b	11.2 a
	Ridomil Plus	25.3 a	23.3 a	60.3 a	12.5 a
Cipira	Unsprayed control	17.0 b	14.9 b	29.6 a	16.5 b
	Anteor Super	20.5 b	19.0 b	37.6 a	16.5 b
	Galben Plus	19.9 b	18.8 b	32.5 a	17.8 b
	Ridomil Plus	29.5 a	28.4 a	36.0 a	26.0 a
Tubira	Unsprayed control	14.2 d	13.4 c	30.8 b	14.2 b
	Anteor Super	18.6 c	17.7 c	38.3 b	14.0 b
	Galben Plus	27.1 b	26.4 b	37.0 b	22.3 a
	Ridomil Plus	32.6 a	31.7 a	51.4 a	19.1 ab

*Means in a column for each variety followed by the same letters are not significantly different according to Duncan's multiple range test ($p = 0.05$).

Table 6: Correlations between SAUDPC and yield variables for seed and ware potatoes.

Character	Seed grade	Seed potatoes	Ware potatoes
Tuber number		-0.55***	-0.52***
Tuber weight		-0.24ns	-0.32*
Tuber yield	Grade I	-0.15ns	-
	Grade II	-0.67***	-
	Grade III	-0.38*	-
Marketable yield		-	-0.82***
Total yield		--0.71***	-0.81***

Significant at *** $p = 0.001$ or * $p = 0.05$, ns = non significant.

*Seed tuber sizes were ≤ 25 mm for grade I, 25 – 55 mm for grade II and ≥ 55 mm for grade III.

efficient treatment for Desirée and Tubira, while Galben Plus was the most efficient for Cipira. The most cost-effective combination was Tubira-Ridomil Plus, followed by Tubira-Anteor Super and Cipira-Galben Plus treatments. The use of Anteor Super on Desirée resulted in negative returns (Table 8).

The returns to fungicide treatments in ware potatoes are presented in Table 9. The highest increase in net returns was obtained with Ridomil Plus sprayed plots of all varieties, followed by Galben Plus on Desirée or Tubira

or Anteor Super on Cipira. Tubira–Ridomil Plus treatment was the most cost effective combination for ware potatoes (Table 9).

Discussion

Late blight was most severe in unsprayed plots than in sprayed plots. Desirée was the most susceptible variety, while Cipira and Tubira had the same level of disease resistance. Ridomil Plus was consistently the most effective fungicide for seed and ware potatoes, followed by Galben Plus and Anteor

Table 7: Cost of fungicides used in the production of one hectare of potato.

Fungicide	Quantity (kg/ha)(a)	Unit cost (US \$)(b)	Number of applications (c)	Labour for application (d)	Total cost [(a)xbxc + d]
Anteor Super	3	12.15	2	15.00	87.90
Galben Plus	2.5	20.00	2	15.00	115.00
Ridomil Plus	2.5	21.43	2	15.00	122.15

NB: All costs are in US \$/ha, 1 US \$ = 700 FCFA.

Table 8: Economic analysis for fungicidal control of late blight in one hectare of seed potatoes.

Variety	Fungicide	Fungicide cost (TC)	Returns per tuber grade*			Total return (TR)	Net return (TR-TC)	Increase in NR
			I	II	III			
Desirée	Control	0	171.43	5,857.14	114.28	6,142.85	6,142.85	-
	Anteor Sup.	87.90	171.43	5,785.71	214.28	6,171.42	6,083.52	- 59.33
	Galben Plus	115.00	228.57	6,714.28	42.85	6,985.70	6,870.70	727.85
	Ridomil Plus	122.15	114.28	7,285.71	514.28	7,914.27	7,792.12	1,649.27
Cipira	Control	0	742.86	6,071.43	42.85	6,857.14	6,857.14	-
	Anteor Sup.	87.90	514.29	7,071.42	514.29	8,100.00	8,012.10	1,154.96
	Galben Plus	115.00	628.57	8,928.57	600.00	10,157.14	1,0042.14	3,185.00
	Ridomil Plus	122.15	171.43	8,928.57	685.71	9,785.71	9,663.56	2,806.42
Tubira	Control	0	171.43	6,142.86	100.00	6,414.29	6,414.29	-
	Anteor Sup.	87.90	228.57	9,714.28	114.28	10,057.13	9,969.23	3,554.94
	Galben Plus	115.00	342.86	8,285.71	85.71	8,714.28	8,599.28	2,184.99
	Ridomil Plus	122.15	285.71	12,857.14	342.86	13,485.71	13,363.56	6,949.27

NB: All costs and returns in US \$/ha; US\$1.00 = 700 FCFA. Seed prices were \$ 1.43/kg for grade I tubers, \$ 0.71 for grade II tubers and \$ 0.14 for grade III tubers.

*Tuber size = ≤ 25 mm in diameter for grade I, 25 – 55 mm for grade II and ≥ 55 mm for grade III.

Table 9: Economic analysis for fungicidal control of late blight in one hectare of ware potatoes.

Variety	Fungicide	Fungicide cost (TC)	Returns per tuber grade		Total return (TR)	Net return (TR-TC)	Increase in NR
			< 20 g	> 20 g			
Desirée	Control	0	20.00	1,842.86	1,862.86	18,62.86	-
	Anteor Sup.	87.90	25.71	2,071.43	2,097.14	20,09.24	146.38
	Galben Plus	115.00	14.29	2,242.86	2,257.15	21,42.15	279.29
	Ridomil Plus	122.15	57.14	3,328.57	3,385.71	3,263.56	1,400.70
Cipira	Control	0	31.43	2,128.57	2,160.00	2,160.00	-
	Anteor Sup.	87.90	42.86	2,714.29	2,757.15	2,669.25	509.25
	Galben Plus	115.00	31.43	2,685.71	2,717.14	2,602.14	442.14
	Ridomil Plus	122.15	31.43	4,057.14	4,088.57	3,966.42	1,806.42
Tubira	Control	0	22.86	1,914.29	1,937.15	1,937.15	-
	Anteor Sup.	87.90	148.57	1,914.29	2,062.85	1,974.95	37.80
	Galben Plus	115.00	20.00	3,771.43	3,791.43	3,676.43	1,739.28
	Ridomil Plus	122.15	25.71	4,528.57	4,554.28	4,432.13	2,494.98

NB: All costs and returns in US \$/ha; US\$1.00 = 700 FCFA. Tuber prices were \$ 0.14/kg for size $\geq$ 20 g and \$ 0.03/kg for < 20 g.

Super. The differences in the performance of these fungicides could be due to either the different systemic active ingredients which are metalaxyl for Ridomil Plus, benalaxyl for Galben Plus, and cymoxanil for Anteor Super or to the differences in percentage of protectant copper oxide (60, 60 or 40, respectively). Although Ridomil Plus was the most effective fungicide, metalaxyl resistant isolates of *P. infestans* have recently been reported in Cameroon (Fontem *et al.*, 2001b), suggesting that resistance to this fungicide can be expected in future. However, these results show that Ridomil Plus is still the best available treatment against late blight. Galben Plus was inferior to Ridomil Plus, but was efficient on Cipira seed production. Anteor Super may not be suitable especially on Desirée, where negative returns were obtained.

Tuber number, total yield and grade II seed tuber yields were highly negatively significantly correlated to SAUDPC, suggesting that the higher the disease intensity on potato, the lower the above-yield components. The highest seed and ware potato yields were obtained in plots treated

with Ridomil Plus, indicating that this fungicide was more effective than the two other fungicides. It is important to note that overall yield results from multiplicative effects of mean tuber number and mean tuber weight (Mendoza, 1995). It appears, therefore that these two components play a major role in the superior performance of Cipira and Tubira. Both varieties had a significantly higher mean tuber number than Desirée, although the mean tuber weight for Desirée was significantly higher than those of Cipira or Tubira. Since tuber number and weight were highly linked to disease pressure in the field, then a mean number of 15 to 18 tubers of 50 – 60 g would provide a potential yield of 30 t/ha or more (Mendoza, 1995).

Although Ridomil Plus was more costly than Galben Plus or Anteor Super, it significantly provided the highest returns in seed and ware potato crops. However, Galben Plus registered the highest increase in net return for Cipira (\$ 3,185.00/ha), closely followed by Ridomil Plus (\$ 2,806.42/ha). Consequently a farmer who treats his/her farm with Ridomil plus may have an increase net return ranging from \$ 1,649.27 to 6,949.27/ha

for seed potato or \$ 1,400.70 to 2,494.98/ha for ware potato depending on the variety used. Moreover, a farmer who treats his/her farm with Galben Plus, may register an increase in net return between \$ 727.85 and 3,185.00 for seed potatoes or \$ 279.29 and 1,739.28 for ware potatoes. These returns are similar to those reported earlier for the susceptible potato variety (Fontem, 2001).

Conclusion

This study shows that late blight is significantly more severe in unsprayed potato plots than in fungicide-sprayed seed or ware potato plots. Although a significant reduction in late blight severity with subsequent improvement in seed and ware potato yields was obtained in all the sprayed plots, these attributes varied with variety and the fungicide used. Ridomil Plus was the most cost-effective co-formulated fungicide against late blight infection in seed and ware potatoes. Results show that late blight infections may decrease potato yields and consequently net farm returns if appropriate management measures are not undertaken. Tubira produced the highest seed and ware potato yields, while Desirée produced the least.

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Assessment of genetic diversity, farmer participatory breeding, and sustainable conservation of Eastern African sweetpotato

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Abstract. Sweetpotato [*Ipomoea batatas* (L.) Lam] is one of the most important crops in densely populated East Africa. The crop is vital to small-scale farmers with limited land, labour and capital. A project funded by the Collaborative Crop Research Programme (CCRP) of the McKnight Foundation was initiated from July 2002 to run for four years. Project partners are the Kenya Agricultural Research Institute (KARI), Louisiana State University, The International Potato Center (CIP), Austrian Research Centers-Seibersdorf and the Root and Tuber crops programme of Tanzania. This project aims at improving East African sweetpotato productivity and sustainability through collaborative and participatory research on germplasm conservation, crop improvement, and development of technology for planting material production. So far a total of 679 sweetpotato germplasm accessions have been collected in eight regions of Kenya and Tanzania. Focussed Participatory Rural Appraisals to collect indigenous technical knowledge on sweetpotato germplasm have been conducted in 25 communities in six sweetpotato production regions. Twenty high dry matter and β -carotene rich sweetpotato clones were transferred from CIP-Lima to four SSA countries. A publicly accessible website www.viazitamu.org has been established to support the project, enable online access of

germplasm records, as well as share information with the general public. A publicly available, license-and royalty-free, web based GIS viewer for use on the web site has been adapted. Six local orange and yellow fleshed varieties were virus-tested and are being cleaned and multiplied for dissemination to farmers. A number of partner NGOs and CBOs have established field seed multiplication nurseries for distribution as co-funded activities. KARI and LZARDI have also established basic seed nurseries.

Introduction

Sweetpotato [*Ipomoea batatas* (L.) Lam] is the world's seventh most important food crop after wheat, rice, maize, potato, barley, and cassava (CIP, 1996). It is one of the most important crops in densely populated East Africa (Low *et al.*, 1997). The crop is vital to destitute small-scale farmers with limited land, labor and capital. The crop grows well on soils with limited fertility, is relatively drought tolerant, provides good ground cover, and is usually cultivated without fertilizer or pesticides (Ewell, 1990). Traditional cereal crops often fail in these same environments. Sweetpotato also thrives in fertile environments, producing remarkable amounts of energy quickly, often producing more edible energy than any other major food crop (CIP,

1996). Sweetpotato roots provide energy, little but high quality protein (e.g. lysine), Vitamin B1, B2, niacine, pyridoxine, folic acid and ascorbic acid (Woolfe, 1992). Orange-fleshed sweetpotato have reasonable quantities of β -carotene, a precursor for Vitamin A (Hagenimana *et al.*, 1999). Other important nutrients found in sweetpotato include calcium, phosphorus, iron, sodium and potassium. In short, it has great potential in combating the food shortage and rampant malnutrition in this region. Sweetpotato is utilized as a tropical salad, a staple or vegetable food, a sweet dessert, a fast food, an animal feed, or a basic industrial raw material (Woolfe, 1992). The value of sweetpotato is now being recognized and rewarded with increased funding by national and international agricultural research centres. The national programmes, together with the international agricultural research centres and other institutions, have made significant progress in germplasm conservation and crop improvement in East Africa. However, an institutional mechanism is needed to sustain and speed up the progress.

Sweetpotato originated in the Central and Southern America, although the precise location remains unknown (Woolfe, 1992). The crop was introduced to Europe through Spain in the 15th century, from where it was further dispersed to the rest of the world. The Portuguese are thought to have introduced the crop to Africa through Mozambique and Angola. The British colonialists may also have brought sweetpotato from India in the 17th and 18th centuries. East Africa is believed to be a secondary centre of diversity of the sweetpotato. This diversity needs to be assessed, conserved and utilised for the benefit of the farmers in the region.

The major constraints to sweetpotato production include continued use of low yielding and late maturing local cultivars, post harvest yield losses, diseases and pests and inadequate planting material. The major pests includes insects such as the sweetpotato weevils, vertebrate pests such as moles, rats,

porcupines and monkeys (Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995). The most important disease in Kenya is the sweetpotato virus disease (SPVD) (Wambugu, 1991). In addition there is poor institutional support and recognition and inadequate research capacity in most African countries.

A project funded by the Collaborative Crop Research Program of the McKnight foundation aims at improving regional sweetpotato productivity and sustainability through collaborative researches on germplasm conservation, crop improvement, and development of technology for planting material propagation. These research activities will be carried out in a multi-disciplinary framework including national programmes and advanced institutions. There will be extensive capacity building for the national scientists both through degree training and on-job, specific training programs. The outcomes of this project will greatly contribute to conservation of sweetpotato genetic diversity, increased sweetpotato productivity, enhanced sustainability of sweetpotato based production system, improved nutrition status, disaster preparedness, and strengthened sweetpotato research capacity in East Africa. The key partners in this initiative are, The Kenya Agricultural Research Institute (KARI), The Ministry of Agriculture and Food Security of Tanzania, National Root Crop Program, Louisiana State University, Austria Research Centers Seibersdorf and the International Potato Center. The project targets resource poor farmers in the three East African countries, Kenya, Uganda and Tanzania.

Documentation of indigenous technical knowledge. For technology transfer to be efficient, the needs of the clients must first and foremost be established. The client, in this case the farmer, must participate in the process of identifying technologies that might solve his problems. The project has used Participatory Rural Appraisal (PRA) methods

to collect indigenous knowledge on germplasm conservation and role of sweetpotato in the farming system.

The objective of the PRAs was to identify current sweetpotato production constraints, its productivity and sustainability within the farming systems, genetic diversity, production systems and other positive aspects that contribute to the enhancement of livelihoods of farmers. Sites were selected with the assistance of extension staff using criteria such as agro ecological representation, farming systems and the diversity of sweetpotato varieties grown in the area. Farmers listed and prioritized agricultural constraints they experienced and suggested solutions to alleviate them. Activities and tools used included historical profiles, matrix and pairwise ranking of enterprises, collection and reviewing of secondary data, access and control profiles by gender, problem-causal analyses and potential solutions, village mapping, seasonal calendars and cropping activity calendars

The PRAs took 1-3 days depending on ease of access, availability of secondary data and farmers availability. Initially, a meeting was called with community leaders and the local administration. Checklists were prepared for use by the multidisciplinary teams, which included breeders, agronomists, social scientists and extension staff and where possible an entomologists or pathologist.

In Kenya PRAs were conducted in a total of 15 communities in four regions (Table 1). In Tanzania 10 villages in two zones were

covered (Table 2). Several production constraints were identified in each area including;

1. Rotting of sweetpotato tubers in dry period (associated with sweetpotato weevils)- Farmers do opt to process sweetpotato when rain season stops.
2. Pests and diseases - Farmers have no solution. They still depend on the susceptible varieties
3. Insufficient rainfall especially in Meatu and Magu districts- No solution to this problem.
4. Limited land for sweetpotato cultivation which is caused by different factors like overpopulation and overstocking- Farmers have no solution to that problem

Table 1: Location and number of villages where participatory rural appraisals were carried out in Kenya.

Region	Area	Number of villages
Western Kenya		3
South West Kenya	Rongo	2
	Ndhiwa	1
	Kabondo	2
	Kendubay	1
Eastern Kenya	Kangundo	1
	Kangundo	1
	Matungulu	1
Central Kenya	Mukurueni	3
	Kibirigwi	1

Table 2: Location and number of villages where participatory rural appraisals were carried out in Tanzania.

Region	District	Sample villages
Lake Zone	Sengerema	Nyamadoke, Igurumuki
	Magu	Kabita, Mwamabanza
	Meatu	Bulyashi, Mwanjolo
Lake zone	Ilala	Chanika
	Tanga	Mombo
	Morogoro	Sanje
		Msolwa

5. Lack of improved sweetpotato varieties
6. Inadequate planning material

Several important issues were also raised by farmers which included;

- Soil fertility - In all villages it was mentioned to be declining over time, hence need consideration for improvement. The problem is reflected in yield reduction. Soil fertility declined due to continuous cultivation without replenishment.
- Water resources - Water resources were mentioned to be declining over the past ten years, this affected the planting material preservation over seasons.
- Competition between livestock and crop production. This has implications in land allocation depending on the ranking and value of the enterprise
- Human population - Increasing population had led to food insecurity in many areas. Expansion of sweetpotato production areas and introduction of high yielding sweetpotato varieties is desirable in most areas.
- Institutions - Several institutions exist in most project areas with potential support for the distribution of improved varieties and planting material.
- Importance of sweetpotato in comparison with other crops. This varied between villages depending on rainfall, soils, markets, biotic constraints and use. In some dry areas the rank was very high while in areas with heavy rains it was ranked low because farmers grow other higher value crops. Hence there is room to improve production of sweetpotato in areas where the ranking of sweetpotato was high, but the room for expansion can also be considered in the other areas for purposes of food security and after addressing specific constraints identified. There are also socio-cultural values attached to the crop. In most areas it is regarded as the women's crop.
- Income - Generally, crop production is the main source of income for most communities. This contributes more than 50% of the total income available to the farm families. Improved sweetpotato varieties and marketing may therefore significantly improve farmers' income.
- Expenditure - Very low investments in agriculture was noted in most of the villages surveyed. Although agriculture was an important source of income, most of the income generated was used for purchase of food, clothes and domestic needs.
- Time use profile - Women contribution to labour is very high. Sweetpotato production in most villages is done by women, with small contribution of men. Introduction of high yielding, early maturing varieties will reduce the area to be cultivated per season while maintaining the total yield per season hence reduce work load on women. Technologies developed for labour saving can be important for example; processing equipment, ox-drawn implements and cultivation technologies.

Strengths, weaknesses, opportunities and threats (SWOT) analysis were done for each village. This was followed by development of intervention recommendations for each village.

Germplasm collection. The project aims at collecting germplasm in selected agro-ecologies and recording minimum morphological characteristics and farmer knowledge of the varieties during the collection exercises. Use of Geographical Information Systems (GIS) to select target agro-ecologies is encouraged. In addition existing diversity knowledge is used to determine areas of maximum diversity and plan collection strategies. So far a total of 679 accessions have been collected. A total of 260 accessions have been collected in four regions of Tanzania (Table 3) and 419 accessions in

Table 3: Sweetpotato germplasm collection locations and numbers in Tanzania.

Zone	District	Number of accessions collected
Lake zone	Meatu, Sengerena, Magu, Bukoba Tarime	97
Eastern zone	Ilala, Temeke, Bagamoyo, Kisarawe, Bagamoyo	73
Northern zone	Mwanga and Same	85
Southern	Mbeya, Songea	5

Table 4: Sweetpotato Germplasm collection locations and numbers in Kenya.

Region	Areas	Number of accessions collected
Western	Kakamega, Siaya, Vihiga, Teso, Busia, Bungoma, Kisumu	189
South Western	Migori, Rachuoonyo, Homabay, Kisii	146
Eastern	Kangundo, Matungulu, Kathiani	42
Central	Mukurueni, Kibirigwi, Kieni	42

four regions of Kenya (Table 4). In Tanzania the highest number of collections were in the Lake and Eastern zones while in Kenya the highest numbers were in the western and south western regions. Several reasons were cited by farmers for selecting or abandoning varieties. These include, taste, marketability, tolerance to pests and disease, drought tolerance, yields, maturity period and utilization. Adoption of new varieties must satisfy these multiple criteria. Participatory breeding approaches are therefore recommended to increase adoption rates.

A publicly accessible web site www.viazitamu.org has been established to support the project, enable online access of accession records, as well share information to site visitors.

A publicly available, license- and royalty-free, web-based GIS viewer for use on the web site was adapted. A preview version can be accessed via the “Objectives” link on the main menu. Work is currently ongoing to test and evaluate the GIS viewer as well as incorporate preliminary sweetpotato accession information from the different research partners. The usage logs indicate that the GIS viewer preview page is one of the frequently visited pages on the web site.

Germplasm evaluation and introduction of high dry matter, high beta-carotene content varieties. Up to 20 high dry matter, β -carotene rich sweetpotato clones have been received *in-vitro* from CIP – Lima. These clones have been multiplied in green houses and fields and are ready for field evaluations. Earlier CIP introduced orange-fleshed varieties still maintained at PQS Muguga were distributed to various countries in the region where they are being tested for adaptability and acceptability. Evaluation of local orange-fleshed varieties is being carried out in Kenya (Kabete, Kakamega). Those that have been found acceptable to communities are currently being multiplied by partner NGOs and CBOs for distribution to farmers.

Production of clean planting material. Availability of healthy planting materials of improved sweetpotato varieties is a prerequisite to realizing high root yield. Full access by farmers to new improved sweetpotato varieties is dependent on multiplication and distribution of clean planting materials. Supply of planting materials from research has not met the demand by farmers because sweetpotato like any other vegetative plant has low

multiplication ratio. In most seasons most farmers suffer shortage of planting materials, which has resulted into most fields being not planted with sweetpotato. Non-government organizations have been supportive in multiplication and distribution of planting materials. The objective of basic seed production was to establish sweetpotato seed nurseries to act as source of nucleus planting materials for secondary multiplication by farmers, NGOs and CBOs.

Six varieties were tested for viral infections, cleaned and multiplied at PQS Muguga. These were local orange and yellow-fleshed varieties. A number of partner NGOs have established field seed multiplication nurseries for distribution as co-funded activities. In Kenya REFSO and UCRC have established nurseries in swampy areas to ensure continuous supply of planting materials to farmers. This is in addition to the nurseries being maintained at KARI-Kakamega, KARI Kisii, KARI Katumani and Kabete field station in Nairobi.

During the 2002 season, in anticipation of food shortages due to drought, the Tanzanian government insisted on each household growing drought tolerant crops particularly cassava, sweetpotato and sorghum. This was to make sure that every household is self sufficient in food supply to mitigate food insecurity in extended periods of drought. Lake zone Agricultural Research and Development Institute (LZARDI) responded by multiplying and distributing sweetpotato planting materials to farmers for secondary multiplication. This activity was done in collaboration with CARE International, an NGO operating in Misungwi and Magu and the district covered was Misungwi.

Varieties that were multiplied and distributed from sweetpotato seed nurseries at LZARDI, Ukiriguru were Simama, Jitihada, Vumilia, Mavuno and Sinia, which are officially released varieties. Other varieties include NC 1560, Mafutha, Japon Tresimesino and Tainung No. 64. These are some of the orange-fleshed sweetpotato varieties that have been tested on farm for acceptability.

Tests done in 2001 and 2002 seasons have shown most of them to be acceptable by farmers.

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Development of virus resistant sweetpotato using biotechnological approaches in Kenya

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Abstract. The sweetpotato virus disease (SPVD) is one of the main constraints to sweetpotato production in Africa. It is caused by a number of sweetpotato viruses. The sweetpotato feathery mottle virus (SPFMV) is the most widespread of those viruses. Transformation of sweetpotato plants with viral coat protein genes may impart a coat protein-mediated resistance to SPVD. In 2001 twelve lines of sweetpotato variety CPT 560 transformed with the SPFMV coat protein gene were field tested under controlled conditions in four important sweetpotato growing agro-ecologies in Kenya. Based on virus resistance, yields of storage roots and vines, four transgenic lines were selected and evaluated further in 2002. Results from these field trials did not provide an adequate level of SPVD resistance as expected based on visual assessment of symptoms and tissue printing bioassays. Possible explanations for this unsatisfactory level of protection may be due to synergistic effects of other sweetpotato viruses in the environments where the lines were tested. Secondly it is possible that the first generation gene constructs were not efficient against the Kenyan strains of the virus since they were developed based on American strains of the virus. The second generations of transgenic plants are currently being developed at the Kenya Agricultural Research Institute (KARI) Biotechnology centre and are at various stages of development. These have improved gene constructs developed using

Kenyan isolates of SPFMV. This project has been instrumental in development of the biotechnology framework in Kenya and capacity building in biotechnology.

Introduction

There is sufficient evidence that biotechnology has potential to boost global agricultural productivity in a sustainable way. The prospects are particularly bright for developing countries where conventional methods of breeding have not been able to cope with the myriad biotic and abiotic challenges constraining the agricultural sector. Being the economic mainstay for the majority of these countries, the sector's poor performance has contributed significantly to the escalating food insecurity, malnutrition, poverty and environmental degradation particularly in Africa. This has led many African governments and researchers to intensify the search for appropriate interventions including the integration of the cutting edge science of biotechnology into conventional approaches to agricultural commodity improvements. Problems however arise because the research capacity (human and infrastructural) in most of these countries is limited and the industrial world has dominated the biotechnological revolution, concentrating on crops perceived to be of global economic importance. African countries could import some of these technologies, but they are not usually tailored

to the needs of small-scale subsistence farmers. In addition, “orphan crops” that are important to small-scale farmers but do not attract much research support internationally, would be neglected. One such crop is the sweetpotato [*Ipomoea batatas* (L.) Lam]. Sweetpotato is the world’s seventh most important food crop after wheat, rice, maize, potato, barley, and cassava (CIP, 1996). It is one of the most important crops in densely populated East Africa (Low *et al.*, 1997). The crop grows well on soils with limited fertility, is relatively drought tolerant, provides good ground cover, and is usually cultivated without fertilizer or pesticides (Ewell, 1990). Traditional cereal crops often fail in these same environments. Sweetpotato also thrives in fertile environments, producing remarkable amounts of energy quickly, often producing more edible energy than any other major food crop (CIP, 1996). Despite the crop’s importance for human nutrition and environmental conservation, yields in Africa remain low – about 6 tons/ha compared to the global average yield of 14 tons/ha and a yield potential of more than 40 tons/ha (Ndolo *et al.*, 1996).

The major constraints to sweetpotato production include continued use of low yielding and late maturing local cultivars, post-harvest yield losses, diseases and pests and inadequate planting material. The major pests includes insects such as the sweetpotato weevils, vertebrate pests such as moles, rats, porcupines and monkeys (Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995). The most important disease in Kenya is the sweetpotato virus disease (SPVD) (Wambugu, 1991). In addition there is poor institutional support and recognition and inadequate research capacity in most African countries.

In Kenya, the sweetpotato is an important food security and cash-generating crop with about 750,000 tons of fresh tubers being produced annually on an estimated 75,000 ha of land (FAO, 1999). The crop is also important for human nutrition especially the orange-fleshed varieties which contain high levels of b-carotene useful in combating vitamin A

deficiency in children under the age of five and breast-feeding mothers (Low *et al.*, 1997). The Lake Victoria basin and the western Kenya highlands accounts for over 70% of national production followed by the Central Highlands and Eastern Kenya producing about 20%. Production is mainly by small-scale farmers.

The sweetpotato virus disease (SPVD) and the sweetpotato weevils are the main biotic constraints. In Kenya, the weevil is the single most important biotic production constraint and may account for losses of up to 80% on individual farms (Smit, 1997; Ngunjiri *et al.*, 1993). Among the viruses, the sweetpotato feathery mottle virus (SPFMV) is the most widespread in Kenya (Wambugu, 1991). The SPFMV belongs to the *Potyvirus* genus in the family *Potyviridae*. It occurs everywhere sweetpotatoes are grown, including Africa. SPFMV is transmitted non-persistently by aphids. It is not considered as a serious production constraint on its own. However, when it interacts with the sweetpotato chlorotic stunt virus (SPCSV), transmitted by the whitefly, it results into the sweetpotato virus disease complex (SPVD).

Biotechnological approach to virus resistance. Over the years researchers at the Kenya Agricultural Research Institute (KARI), in collaboration with the International Potato Center (CIP) have established that sweetpotato viruses have significant economic importance and that available virus control methods are ineffective or unaffordable by resource-poor farmers in Kenya. In 1991, KARI initiated a collaborative project having reached the conclusion that a biotechnological approach to virus resistance would add value to the search for a long-term solution for the control of SPFMV.

The project has been collaboratively carried out between KARI, Monsanto Company-USA, Danforth Plant Science Centre-USA, Agricultural Research Council (ARC)-Roodeplaat, Vegetable and Ornamental Plant Institute-South Africa, United States Agency for International Development

(USAID) and the International Potato Center (CIP). The International Service for the Acquisition of Agri-biotech Applications (ISAAA) brokered the project, which involved: negotiations for intellectual property (IP) rights donation, Material Transfer Agreements, fund-raising and identification of appropriate partners for the different implementation stages.

The broad objective of this partnership was to transfer virus resistance traits via genetic engineering to Kenyan sweetpotato varieties for use by subsistence farmers. Specific objectives were to identify effective improved gene-construct/s, to build transformation capacity in Kenya, to transform local popular sweetpotato varieties, to test agro-ecological adaptation of transgenic sweetpotato through participatory methods, and to assess and identify impact of genetic engineering technology in smallholder farming systems.

Technology development and mock trials.

Coat protein mediated resistance (CP-MR) for SPFMV control is a form of genetically engineered resistance, whereby the expression of viral coat protein genes in the transgenic plants induces a cross “protection-like” phenomenon that confers resistance to the virus from which the gene was initially derived as well as to related viral strains (Beachy *et al.*, 1990). It is still largely unclear what the molecular mechanisms of CP-MR are although some theories have been proposed. Monsanto donated the gene constructs and initial research on genetic transformation of six Kenyan sweetpotato varieties against SPFMV was done at Monsanto laboratories in the US. At the initial stages of the project, only one of the six sweetpotato varieties, CPT 560, was readily transformed with the donated constructs (Gibbons, 2000). The actual transfer of the transgenic sweetpotato technology from Monsanto to KARI took place in the year 2000.

Mock trials were carried out with conventional CPT 560 and other local varieties

to familiarize KARI staff members with general trial procedures for the safe handling of transgenic crops. This was done prior to importation of the transgenic material. KARI and Monsanto scientists developed the transformation and regeneration protocol of sweetpotato variety CPT 560 at Monsanto Company, St. Louis (USA).

Field trials in Kenya. This activity was aimed at evaluating agronomic performance, ecological adaptability and virus resistance ability of transformed (transgenic) CPT 560 under field conditions in Kenya. The first round of field trials was carried out during 2000/2001 at four centres of the Kenya Agricultural Research Institute namely the Regional Research Centre (RRC) Mtwapa located in the Coastal Lowlands, RRC Embu in Eastern Province, the National Agricultural Research Laboratory (NARL), Kabete on the outskirts of Nairobi and RRC Kakamega in Western Province. It involved 12 transgenic lines of sweetpotato variety CPT 560. During the trials, data were collected on crop establishment and crop vigour based on protocols developed by researchers at the International Potato Centre (CIP). Based on agronomic performance and virus resistance data using visual symptoms and NCM Elisa tissue print bioassays four transgenic lines were selected for the second round of field trials in 2002 across all the four agro-ecologies.

Prior to the introduction of the transgenic sweetpotato, Kenya had no operational biosafety system. The need to evaluate the genetically modified (GM) material stimulated the development and institutionalization of national biosafety guidelines and regulations. During the trials, measures were taken to minimize the chances of gene transfer between the trial crops and cultivated sweetpotatoes or their wild relatives. This was achieved through: Security enclosure using chain-link wire around all trial sites

- 24-hour security surveillance systems
- Restricted entry to the trial sites

- Regular monitoring and emasculation of flower buds from test plants
- Inclusion of guard rows and a barrier crop around the test site
- Destruction by burning of all material after harvest

Results from these field trials did not provide an adequate level of SPVD resistance as expected based on visual assessment of symptoms and tissue printing bioassays. A possible explanation for this is the synergistic effects of other Sweetpotato viruses in the environments where the plants were tested. Secondly the gene constructs used were developed from American strains of the virus whereas African strains are more virulent.

Current activities. A second generation of gene constructs has now been developed based on a Kenyan strain of SPFMV. The transformation and regeneration protocol for variety CPT 560 has been optimized at the KARI Biotechnology laboratory in Nairobi, Kenya. Concurrently, regeneration for other popular local varieties is being developed in the same laboratory. In addition capacity for molecular characterization and resistance testing is currently being developed in this laboratory. KARI has also initiated collaboration with Kenyatta university in training and research to enhance capacity building in gene technology in Kenya.

Achievements

The project serves as an example of collaborative linkages between the private and public sectors as well as technology transfer from the north to the south. This project was instrumental in the operationalization of the Biosafety system and opened up the approval system for the introduction of other genetically modified organisms in Kenya. A biosafety permit application for on-station field-testing has been granted to KARI by

the Kenya Plant Health Inspectorate Service (KEPHIS) following approval by National Biosafety Committee.

The sweetpotato project has also helped to create awareness of biotechnology and related biosafety issues in Kenya. In addition, it has been instrumental to the increasing involvement of Kenyan biotechnology stakeholders in the global biotechnology debate.

Intellectual Property Rights (IPR) negotiations between Monsanto and KARI were successfully brokered by ISAAA and a royalty-free license agreement between the two institutions was signed in 1998. The agreement allows KARI to use and further develop the transgenic virus resistance technology in sweetpotatoes. KARI may also protect resulting transgenic varieties under the plant breeders' rights convention or similar regulations in Kenya and transfer the technology to any other country in Africa.

KARI has an operational biotechnology laboratory for further transformation of local African sweetpotato genotypes with technical support from Monsanto, CIP and Danforth Plant Science Centre. This laboratory is manned by fully qualified Kenyan scientists. In addition, KARI has developed full capacity for conducting laboratory, greenhouse and field experiments with transgenic plants.

KARI has also developed capacity to engage in genetic engineering for other traits in sweetpotatoes and other important crops. New improved gene constructs developed using a Kenyan SPFMV isolate have been used to transform a few popular sweetpotato lines. Some of these are undergoing multiplication, molecular characterization and virus challenge trials at the KARI Biotechnology centre. Institutions involved in biotechnology and biosafety development should establish linkages with centers of excellence to ensure access to the most up to date information.

Future activities

Recent studies indicate that the SPCSV is a key virus in the development of the SPVD. The sweetpotato weevil is also a major constraint to sweetpotato production. Pyramiding of virus and weevil resistance to ensure success in improvement of sweetpotato crop yields is an important objective for the future of this project. Future evaluations will also include food and environmental safety. Eventual commercialisation of the transgenic sweetpotato will follow assessment of its potential. The experiences gained in Kenya will be shared with partners in the ASARECA (Association for Strengthening Agricultural Research in East and Central Africa) region.

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Development of a web-accessible GIS database of sweetpotato germplasm for East Africa

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Abstract. Despite the potential of GIS systems to provide vital spatial and temporal information to target clientele, accessibility by users without direct access to these databases is often limited. Web-based delivery represents a method of delivering real-time or near real-time data to clientele. Although proprietary methods are available for delivering GIS data through web interfaces, these methods often require expensive licensing agreements. The availability of publicly available software that require minimal or flexible licensing costs provide a cost-effective alternative to institutions that are considering access to GIS databases via a web-accessible interface. We describe procedures, software, and other applications that we used to develop a publicly accessible web interface to a GIS database of sweetpotato germplasm collections in Kenya, Tanzania, and Uganda.

Introduction

Visual representation of information based on data stored in a spreadsheet format or computer databases represent the compelling advantage of using GIS systems to deliver pest surveillance, agroclimatic data, germplasm accession, and other data to growers and other clientele. The use of GIS makes possible the integration of diverse spatial data into a comprehensive database (Rao *et al.*, 2000). Despite the potential of GIS

systems to provide vital information to clientele, user access and knowledge are among the impediments to using such systems in real world applications (Zerger and Smith, 2003). Web-based methods represents a viable option to deliver GIS data to users. Although proprietary methods are available, these often require expensive licensing agreements. The availability of open specification and open source software that require minimal licensing agreements provide institutions with cost-effective tools in providing web access to GIS databases.

We describe procedures, software, and other applications that we used to develop a publicly accessible web interface to a GIS database of sweetpotato germplasm collections in Kenya, Tanzania, and Uganda.

Materials and Methods

Basemaps and other thematic maps were downloaded from publicly accessible web sites. DIVA-GIS (Hijmans *et al.*, 2002) was used to preview shapefiles as well as create shapefiles from DBF formats. We have previously registered a domain name, www.viazivitamu.org and established a corresponding web site. We used ALOV Map (www.alov.org), a free, portable Java® application for publishing vector and raster maps on the web. The files were initially configured and tested on the desktop by editing the 'sample.xml' file to pinpoint to the

shapefiles and html files. After previewing the html documents and testing the map outputs, all files were subsequently uploaded to the web site. Necessary updates were uploaded as needed.

Results and Conclusions

Figures 1-2 show the map user interface using five shapefiles depicting country administrative boundaries as well as representative sweetpotato accession data and a sample of georeferenced sample sites. This demonstrates desktop GIS-like capabilities of ALOV Map in panning, zooming, and identification of attributes. However, the Java-based applet does not support a number features associated with desktop-based GIS applications. For example, basic analysis features like measurement of

distances and statistical calculations are not currently supported. Despite the lack of analytical and other advanced features, the Java-based GIS mapping application represents an important step in making available GIS-based information on the web. Institutions that do not have adequate resources to license commercial Internet or Web GIS software can immediately offer web-based access to existing GIS files without spending for license fees or requiring existing personnel to undergo training in web development.

Using freely available applications and tools, we were able to publish GIS data via a web interface with a minimum of coding. Although full desktop GIS functionality is not currently available via ALOV Map, this applet provides an option for making current GIS data web-accessible.

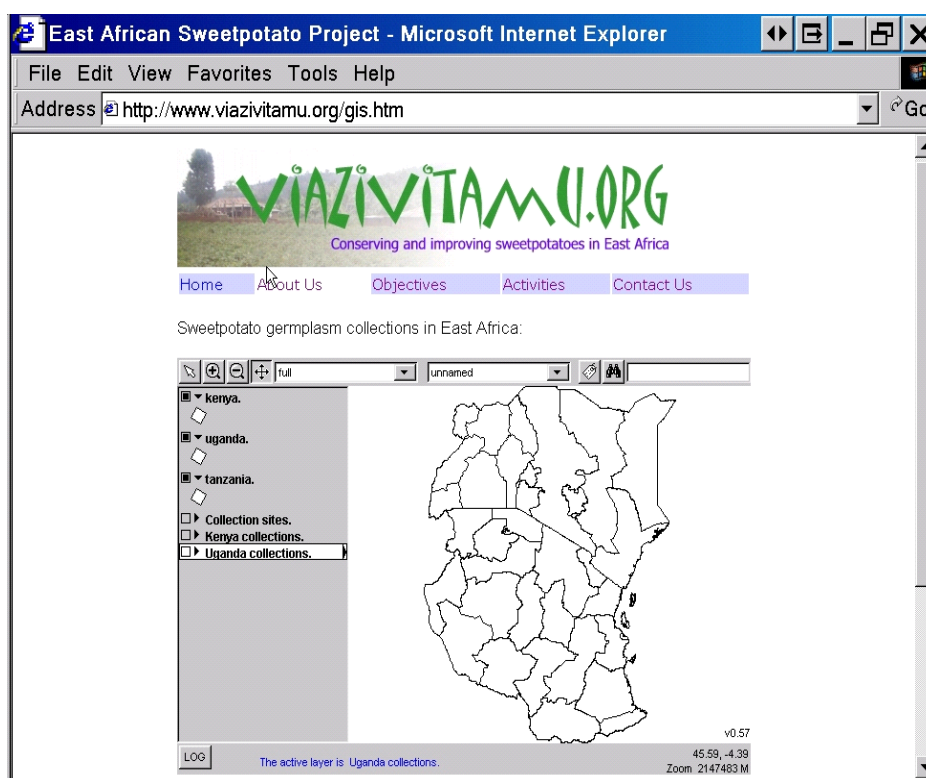


Figure 1: Map user interface for selecting layers, panning, zooming, and identification of attribute data.

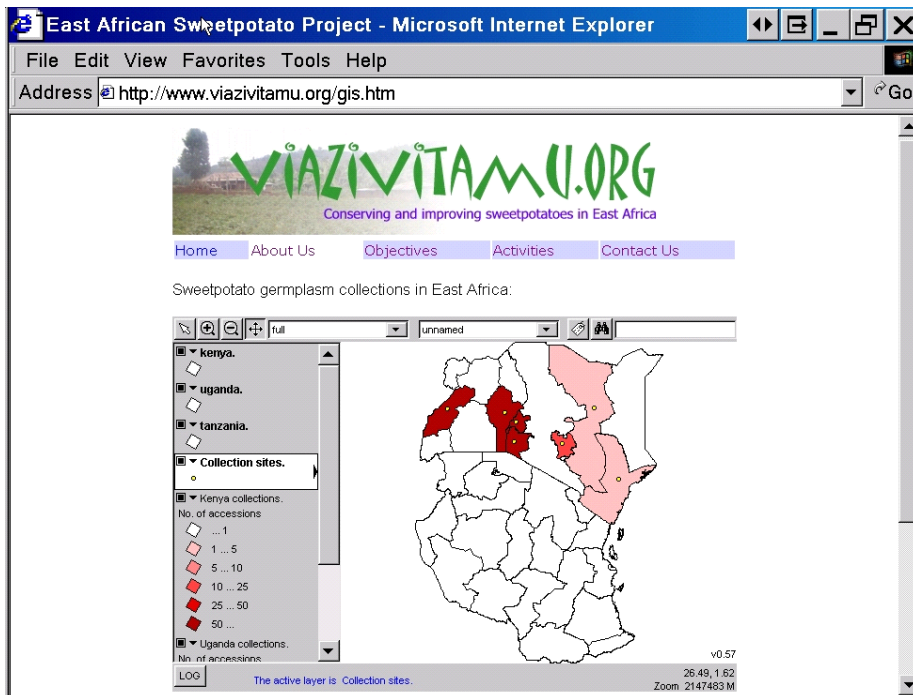


Figure 2: Output after selecting additional layers showing rendering options depicting variation in accession number.

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Molecular markers as a tool for participatory cassava breeding

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Abstract. It is of fundamental importance to know the genetic identity of the plants used in the breeding process and in the case of asexually reproduced crops to know to which clone a plant belongs. Since cassava small-scale farmers do not maintain a one-to-one relationship between variety and clone participatory cassava breeding has a problem using farmer's plants. This study uses molecular markers to identify clones popular by small-scale cassava farmers and to describe the impact of genotype by environment interaction (GxE) on farms. Popular clones are particularly important when choosing local parents for crossings. Better knowledge of GxE at the farm level would improve the selection schemes. Eight SSR markers were found to be sufficient to discriminate between clones. A wide diffusion of a clone was used as an estimate of its popularity. Plants were collected from ten districts of Malawi. Most clones were limited in their geographic distribution. A majority was represented by a single plant but a few were found in several districts. Plants of the clones 'gomani' and 'mbundumali', that for decades have been distributed by the national breeding programme, were collected from farmers in three and nine districts, respectively. There was genetic identity between all 'gomani' collected from the farmers and the 'gomani' in the breeding programme. Plants that belonged to the program clone 'mbundumali' had seven variety names among farmers and these varieties also included a fraction of other

clones. Consequently farmers can maintain varieties as single clones but mostly molecular markers are needed for identification of a plant's genotype. The study also suggests that the major part of the small-scale farmers' clones is used for breeding the rest for production. The analysis of GxE in farmers' fields showed that interaction occurred within farms for variables related to cultivation activities as well as to natural environmental variation.

Introduction

The starchy roots of cassava, *Manihot esculenta* Crantz, have become the most important source of dietary energy in Sub-Saharan Africa (Hillocks, 2002). Cassava is mainly grown by small-scale farmers and about a third of the villages in the cassava growing areas rate it as the most important crop (IITA, 1997). The farmers predominantly grow cassava in marginal environments, that is, under conditions that vary over space and time. Chemical fertilisers are rarely used (Nweke, 1994) but the yields are sustainable over many years, possibly because the foliage is recycled back into the soil. A threat to cassava's survival as a dominant crop in subsistence communities is cassava's vulnerability to diseases. The African cassava mosaic virus, the causal agent to the historically most serious disease to African cassava cultivation (Hahn *et al.*, 1980), has made farmers give up cultivation of cassava

at least for periods (Jameson, 1964; Otim-Nape, 2001). Still it seems realistic to assume that the cassava farming system will remain important to many Sub-Saharan communities and for their development because of its capacity to provide food and market opportunities (FAO, 2000).

The breeding of cassava for Sub-Saharan Africa is conducted by the international community of formal cassava breeders as well as by small-scale farmers. Cassava is an out-crossing crop, but since it is vegetatively propagated it is composed of groups of genetically identical plants, that is, clones. Formal breeders primarily use recurrent selection and multilocation clone trials to develop new varieties (IITA, 1990) but have also started to use marker-assisted selection (Fregene *pers com*). Farmers base their selection on phenotypic characters (Chiwona-Karlton *et al.*, 1998) although evidence of parent-offspring relationships between their varieties (Fregene *et al.*, 2003) indicates that recombination could be an important component in their breeding. However, interviews with small-scale farmers has shown that farmers adopt few new improved varieties, partly as an effect of dismal performance and deficiency in traits that the farmers like (Nweke *et al.*, 1994). This would indicate that formal breeding has a minor impact on the variety composition in Sub-Saharan Africa despite clear evidence of its capacity to reduce disease problems in subsistence farming (Jennings, 1994; Otim-Nape *et al.*, 2001) and to adapt cassava to market needs (CIAT, 2001). As a consequence cassava-breeding programs in this area have opted for participatory plant breeding (PPB) schemes, e.g. Bua (1998) or Fregene (*pers. com*), in which new varieties are produced from crosses between local and improved varieties, a scheme that has shown promising results under conditions similar to those of cassava in Sub-Saharan Africa (Ceccarelli *et al.*, 2001).

As discussed by Sperling *et al.* (2001) PPB involves formal breeders and farmers but also consumers, extensionists, vendors, industry

and rural co-operatives in plant breeding research. However, in this paper it is only considered how formal breeders could interact with farmers to make the PPB more efficient. The first aim is to identify clones that have proven to be widely appreciated by local farmers. As Witcombe and Virk (2001) have pointed out such clones would improve the chances of producing valuable recombinants from crosses between local and improved varieties and therefore reduce the number of necessary crosses in a breeding scheme. The second aim is to analyse if there are GxE interactions within subsistence communities. To our knowledge, such GxE are not considered in the formal breeding of cassava and therefore become a part of the non-repeatable GxE, a condition that makes breeding for small-scale farmers non-optimal. By considering the factors on the farm level that affect GxE in the planning of selection experiments it would be possible to reduce the very high non-repeatable GxE observed for cassava (Mkumbira *et al.*, 2003b).

An obvious approach to identify clones that have proven to be widely appreciated by local farmers would be to look for varieties that occur over large areas, since one could assume that farmers' cassava -varieties, like the varieties produced by formal breeders, are maintained as single clones (Mkumbira *et al.*, 2003a). One way to identify such clones would be to analyse if there exists local names that are used over wide areas. This method was used by Jameson (1964) when he described the diffusion of local varieties in Uganda in the 1950's, and implied that some few clones were dominating parts of Uganda during that period. Otim-Nape (2001), describing the variety composition just before the severe outbreak of mosaic virus in Uganda, also assumed that local names represent single clones and therefore concluded that some few clones dominated parts of Uganda before the outbreak. Otim-Nape (unpublished) also checked their statements by conducting morphologic analysis of the plants.

Identifying clones by local names and morphology may very well be sufficient, but

caution should be applied about jumping to wrong conclusions for different reasons. Plants of a local variety might not all belong to a single clone but the variety could consist of a dominating clone and plants belonging to other clones. Thus molecular marker analysis indicated that varieties kept by subsistence farmers in French Guyana either consisted of mixtures of plants belonging to unrelated genotypes, mixtures of plants that are genetically related or plants of single clones (Elias *et al.*, 2001). Molecular marker analysis in Malawi by Mkumbira *et al.* (2003a), on the other hand, did not suggest that small-scale farmers keep varieties as mixtures of plants belonging to related genotypes. Here a few commonly grown varieties were kept as single clones while most varieties consisted of a dominating clone and a fraction of plants belonging to other genotypes as well. Other reasons for no one-to-one relationship between a local variety and a single clone are the observations of farmers' naming habits (Chiwona-Karlton *et al.*, 1998; Jones, 1959). These indicate that the same name could purposefully be given to different clones and that a local variety, as observed by Fregene *et al.* (2000), could be adopted under different names. There is also evidence that farmers miss-classify varieties that are recently introduced to a village (Mkumbira *et al.*, 2003a), also causing different names for the same dominating clone. Mkumbira *et al.* (2003a) also showed that some botanical keys for cassava are insufficient in making a clear distinction between plants belonging to different clones, since plants of the same clone varied considerably in morphology. This suggests that the use of morphology could be a poor tool to establish one-to-one relationships between local varieties and clones. Molecular marker analysis therefore could be used as a complement to local names and morphological descriptions to analyse the diffusion of single clones.

As regards GxE on small-holder farms, observations under a previous study (Mkumbira *et al.*, 2003a) indicated that it probably exists since farmers did not grow

varieties randomly on the farm but some varieties were preferred on certain sites. However, considering the risk that plants could be classified to the wrong clone by local names or botanical keys the analysis of GxE will be improved if the plants are genotyped by molecular markers.

In this study farmer interviews and molecular markers were combined to analyse the diffusion of cassava clones in Malawi. Plants genotyped in a previous study (Mkumbira *et al.*, 2003a) and belonging to the ten most frequent clones in two adjacent villages in northern Malawi were also used to study GxE in farming communities.

Material and Methods

Study area. The study of GxE in microenvironments and a major part of the analysis of the diffusion of clones was conducted in two blocks, 'Thowolo-B' and 'Matyenda-1', in Nkhata-Bay district (Figure 1), a district with a predominantly rural population of approximately 165,000 (Malawi, 2000). In this district, about 70% of the farmed land is allocated to cassava (Musukwa and Pelletier, 1990). The two blocks are located at the lakeshore zone along Lake Malawi, 475–600 meters above sea level. The farming community in Nkhata Bay district has a long tradition of growing cassava and many of the varieties have been grown for more than fifty years (Berry and Petty, 1992; Chiwona-Karlton *et al.*, 1998). The crop is mainly grown in small fields with no inter-cropping. Since essentially everyone in the area is a cassava farmer mainly using cassava for household consumption, the harvesting is done on a piecemeal basis throughout the year. Most of the planting is done in direct relation to the piecemeal harvesting. This results in fields with a mix of plants at different ages that belong to up to 15 different varieties. The analysis of the diffusion of clones were also made in other parts of Nkhata Bay, besides the two blocks mentioned above, and in several other districts but mainly in Mulanje, Nkhatakota, Mangochi and Zomba (Figure 1).

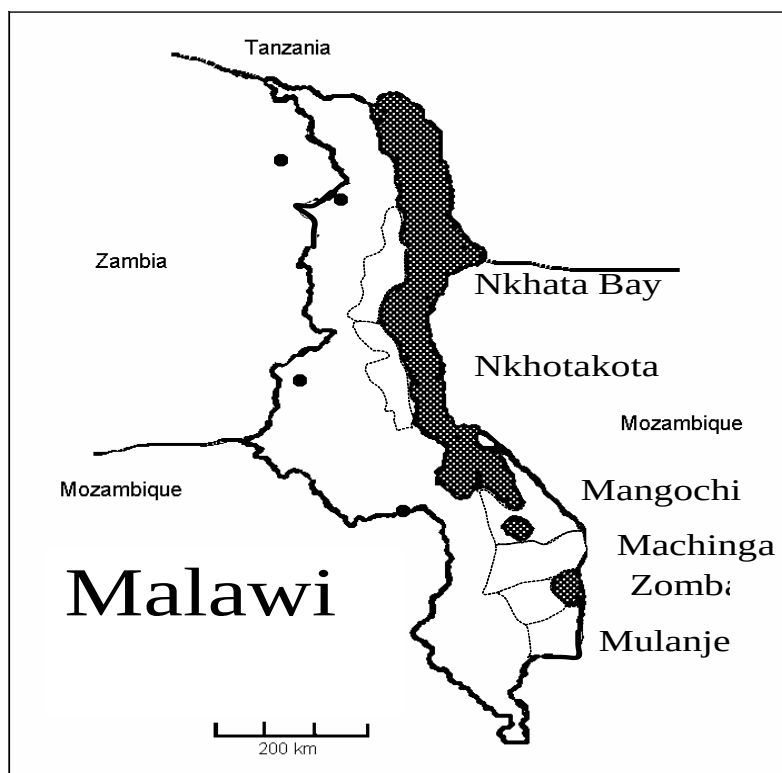


Figure 1: Map of Malawi showing districts where the major part of the collections were conducted.

Nkhatakota, like Nkhata Bay is situated along the coast of Lake Malawi and this district is also similar to Nkhata Bay with respect to agro-ecology and socio-economy but maize is more commonly grown than in Nkhata Bay. The villages studied in Mulanje have frequent rains due to their location in relation to Mount Mulanje and many of the farmers are employed in the tea estates.

They also grow sorghum, millet and maize in addition to cassava. In Machinga and Zomba farmers grow rice, sorghum, millet and maize in addition to cassava.

Interviews with farmers and collections of plants. One of the members of the research team, Linley Chiwona-Karlton, conducted qualitative interviews in Nkhata Bay district during two months in 1994 and 1995, respectively, to elucidate why farmers grow bitter cassava (Chiwona-Karlton *et al.*, 1998).

In July and August 1996 she interviewed all the 176 households in the blocks 'Thowolo-B' and 'Matyenda-1' (Chiwona-Karlton *et al.*, 2000). Later that year a large team collected around 25 plants from each of the ten most grown varieties in the two blocks to study how farmers predict taste and score bitterness of cassava (Chiwona-Karlton *et al.*, 2004) and how farmers classify these varieties (Mkumbira *et al.*, 2003a). These plants were included in this study. The details of the collection procedure, where the farmers were asked to bring two plants from each variety, are described in Mkumbira *et al.* (2003a). In 1997 interviews were conducted in the same blocks with the purpose to understand the farmers breeding practices. Plants from the less common varieties were also collected and genotyped that year and are included in this study. Nearly all the farmers' varieties in the two blocks 'Thowolo-B' and 'Matyenda-1'

were recorded and genotyped since the farmers had been interviewed for the past four years about their varieties and very few new were recorded the last year.

Areas outside the two blocks were visited in 1997, 1999 and 2000 (Table 1 and Figure 1). The research team conducted in-depth interviews with knowledgeable cassava farmers, primarily women, in prior to collecting the plants. In most cases the discussions were in the local language, with simultaneous translation to English, but quite often English was used intermittently. The interviews were conducted to get information on how the farmers acquired, selected and maintained cassava varieties. After the interviews the farmers were asked to bring one plant from each of their varieties. Each farmer only contributed with one plant per variety. In Nkhata Bay and Mulanje the aim was to get as many varieties as possible while the focus was on the commonly grown varieties in the other districts. In addition to the 555 plants collected and genotyped in 1996 – 2000, 68 plants from a national collection, made earlier in the 1990's, were genotyped and included in the study.

Plants of the bitter variety 'gomani' and the cool/sweet variety 'mbundumali' in the Uniform Yield Trial kept at the Research station Makoka in Zomba district were also genotyped. Since these two varieties had been multiplied and distributed through the

national breeding program since the 1970's, the purpose was to check their identity with the plants collected from small-scale farmers.

Molecular marker analysis. Eight highly polymorphic SSR loci, used in an earlier study (Mkumbira *et al.*, 2003a) and possible to combine in more than 10 million genotypes when all alleles are considered and in more than half a million when alleles with frequencies below 0.1 are disregarded, were recorded on all genotyped plants. The DNA techniques were as described in the earlier study. Analysis of molecular variance, AMOVA (Excoffier *et al.*, 1992), was used to estimate variance components within and between districts. It showed that only 4.2% of the molecular variation was between districts indicating that they had minor differences in allele frequencies. The statement 'the probability for finding identical genotypes that are not clones is low' made by Mkumbira *et al.* (2003a) is therefore valid even in this study. Plants genotyped in this study and belonging to the same eight-locus SSR genotype are therefore considered to belong to the same clone.

Identification of appreciated clones. To be able to analyse the occurrence of cassava clones that are liked by the farmers, here called 'appreciated' clones, a definition of such clones is needed. Recently introduced clones,

Table 1: Genotyped plants and number of variety names, clones and 'appreciated' clones.

Area	Genotyped plants	Variety names	Clones	Appreciated clones
Thowolo + Matyenda ¹	290	45	69	29
Chisinga+ Milonde+Nande ²	76	31	29	20
Nkhata Bay (Outside T+M)	64	37	44	25
Nkhotakota	19	9	9	7
Mangochi	25	6	8	4
Zomba	47	15	20	12
Outside the above areas	102	68	52	26
All Malawi	623	165	178	66

¹The two blocks in Nkhata Bay that were intensively studied. ²The three blocks in Mulanje that were most carefully studied.

via cuttings or seedlings, that are represented by some few plants should most probably not be classified as 'appreciated' since they could be poorly evaluated by the farmers. The 18 plants that the farmers classified as belonging to the ten common varieties in Nkhata Bay but that all had unique genotypes (Mkumbira *et al.*, 2003a) could be examples of such clones. A clone that is represented on two different farms, on the other hand, is probably evaluated and accepted by the farmers and such a clone is therefore accepted as an 'appreciated' clone in this study. Since, as mentioned above, the AMOVA indicated that the probability is small to find two identical genotypes that are not clones in the populations from Malawi with the markers used in this study. The minimum requirement for an 'appreciated' clone in this study would therefore be fulfilled if plants with the same genotype were found on two different farms.

Plant characters in the GxE study. The GxE interaction in farmers' fields was analysed using the plants genotyped in the earlier study in the two blocks 'Thowolo-B' and 'Matyenda-1'. In that study a total of 246 plants belonging to the ten most grown varieties in the area were collected from 38 fields, and genotyped using SSR markers (Mkumbira *et al.*, 2003a). For each variety there was one dominating clone and the 181 plants belonging to the ten clones were used for this study. After uprooting, two roots per plant were cleaned by hand to remove the soil, and then weighed. The roots were placed in marked paper bags and transported to Mkondezi Agricultural Research Station laboratory. Root dry matter and cyanogenic glucoside content were determined every afternoon for every sample on the day they were collected. In the laboratory, each root was peeled, washed with tap water and split longitudinally with a sharp knife. One half of the root was used for determining the taste (data not used in this study) and the other half used to determine the dry matter and cyanogenic glucoside content (Chiwona-Karlton *et al.*, 2004). The gravimetric method

was used for dry matter determination, while cyanogenic glucoside levels were determined using the methods of Brimer *et al.* (1997) and Saka *et al.* (1998).

Soil analysis in the GxE study. Soil samples were collected from the top 30-cm at each position where a cassava plant was uprooted and placed in a marked plastic bag. These were transported together with the root samples to Mkondezi Agricultural Research Station laboratory. Soil moisture was determined by the gravimetric method every afternoon on the day the samples were collected. For each sample, 100gm of soil was weighed out and placed in a paper bag and dried in an oven at 110°C until constant weight. The remaining soil samples were later sent to Chitedze Agricultural Research Station for determination of soil pH, organic matter, nitrogen, phosphorus, potassium, calcium and magnesium.

Classification of microenvironments in the GxE study. For each field in which plants were collected the microenvironment was classified for the variables that were considered important for the performance of cassava. The following landforms or physical features of each field and surrounding area as well as operations that farmers had done in their fields at the time of the study were considered:

Anthills. Presence/absence of large termite mounds of soil. The soil is carried and deposited there by the termites while constructing their nest holes underground and could affect an area of up to 100 m².

Topography. Topography was narrowed down to upland or lowland. The uplands were areas on relatively high ground while the lowlands or *dambos* were the relatively small depressions or sunken places and valleys in the area with fairly high water table for most part of the year.

River. Presence/absence of fairly shallow streams of fresh water flowing into Lake

Malawi. The course of most of these streams slightly changes over time due to sedimentation of soil particles eroded from the high grounds. The deposited soil could either predominantly be composed of sand particles or be rich alluvial soils. Farmers often use these patches of land to grow some crops.

Road. Presence/absence of open ways providing passage from one place to another. The soils within and around the 'road' often become more compacted. Plants growing by the 'road' may be disturbed or their leaves/branches may get broken and also more dust particles may settle on their leaves than the plants off the 'road'.

Vegetation. The vegetation around the fields was categorised into two distinct groups: savannah and woodland. The savannah vegetation was characterised by open grassland, usually with scattered trees or shrubs, while the woodland was land mostly covered with woods or dense growth of trees and shrubs.

Land preparation. Traditionally, farmers in this area prefer to grow cassava on mounds, which are small raised mass of soil made at random in the field. The ministry of agriculture, in Malawi, however, has been promoting use of ridges (long narrow raised strips or elevations of soil in ploughed land) as a soil and water conservation measure.

Plant age. A particular feature of cassava is its flexibility in time of harvesting. Farmers, therefore, have the liberty to decide when they can harvest their cassava. A classification into three groups, 6-9, 10-15 and 16-20 months, was used.

Field age. Some fields had been cultivated for more than two years without a fallow break and often grown with the same crop, cassava, while a few were opened and used for the first or second time.

Cropping system. Most often, small-scale farmers plant their crops as mixtures of a number of varieties of different crops (inter-cropping) so as to avoid the risk of crop failure and/or due to limited land for cultivation. Others, however, may grow one or more varieties of a single crop (mono-crop) in each field.

Farm management. Due to one reason or another, farmers fail to weed their fields and this affects the performance of their crops.

Statistical analysis in the GxE analysis. The states of the microenvironments were numerically coded. Regression analysis with stepwise selection was used to analyse the effect of the microenvironments (SAS version 8.2). A moderate significance level of 15% was used at the SLENTY/SLSTAY= level. Thus the *F* statistic for a variable, that is a microenvironment, to be added to the model must be significant at the SLENTY = level. After a variable is added, however, the stepwise method looks at all the variables already included in the model and deletes any variable that does not produce an *F* statistic significant at the SLSTAY = level. Plant age was not included in this analysis since it masked the effect of the other microenvironments.

Results

Farmers' breeding activities. The interviews resulted into some insights into the farmers' breeding practices. The discussions showed that the farmers knew a lot about their varieties. In-depth interviews with some farmers showed that they had developed special techniques to store cutting material and evaluate new introductions. They looked for new varieties from other villages but also from distantly located woods where they found a considerable variation among the cassava plants that were growing wild. In the two areas most intensively studied 'Thowolo-

than one plant and only five of the 34 varieties represented by more than two plants belonged to a single clone. The frequency of plants belonging to a varieties dominant clone, excluding the ten varieties studied by Mkumbira *et al.* (2003a) was 53%. Among the ten studied by Mkumbira *et al.* (unpublished) this frequency was 78%.

Farmers also use several variety names for some of the 'appreciated' clones (Table 2) and particular variety names were given to more than one 'appreciated' clone (Table 2). Even within the two blocks 'Thowolo-B' and 'Matyenda-1' in Nkhata Bay, where ten varieties were observed for 18 to 26 plants, four of them were observed to consist of two 'appreciated' clones each, one grown by many farmers, the other by few.

The plants classified as 'gomani' and 'mbundumali' in the Uniform Yield Trial kept at the Research station Makoka belonged to the genotypes 50 and 41, respectively. All 33 plants called 'gomani' or 'gomani mfipa' by the farmers also belonged to the clone with genotype 50 (see Table 2). The 'mbundumali' plants at the research station belonged to the same clone as 25 of the 28 plants called 'mbundumali' by the farmers. This clone was also found among all the plants that were called 'balaka' (4 plants), 'kabuthu' (2) and 'white' (1) and among the majority of the plants called 'mangochi' (3), 'manyokola' (19) and 'mwaya' (9). Thus the 'mbundumali' plant in the trial belonged to the same clone as 63 of the 79 plants that the farmers claimed belonged to any of the varieties in which this clone dominated and it occurred in nine of the ten districts studied (Table 2).

The effect of microenvironment on GxE. The analyses of farmers' fields from which cassava plants were collected showed the following mean and range over microenvironments (in parenthesis) for soil variables: soil moisture content 8.3 (7.2 – 11.4) %, pH 5.4 (5.2 – 5.8), organic matter 2.0 (1.7 – 3.0) ppm, nitrogen 0.10 (0.08 - 0.20) %, phosphorus 32 (9 – 80) ppm, potassium 0.4 (0.3 - 0.6) Cmol(+)/kg,

magnesium 0.5 (0.1 – 0.8) Cmol(+)/kg and calcium 1.7 (0.9 – 2.5) Cmol(+)/kg. Substantial differences due to topography were shown for all soil factors except pH.

Table 3 shows the number of plants from the ten clones in each microenvironment state. The number and composition of the microenvironments differ considerably between clones. Microenvironments that were included by the stepwise regression model as having a significant contribution to the observed variation for a root yield component are shown in Table 4. More microenvironments were included for the bitter clones compared to the cool/sweet ones. Results of the analysis that included microenvironments interactions have not been included due to small numbers of observations.

Discussion

Diffusion of clones. This study supports earlier findings of a lack of a one-to-one relationship between the farmers' variety names and a single clone. The percentage of plants belonging to a dominating clone was 78% among the ten varieties studied by Mkumbira *et al.* (2003a) in the two blocks in Nkhata Bay but only 53% in the other parts of Malawi. The higher percentage of plants in the two blocks belonging to dominant clones could be due to a more careful sampling and/or an effect of a higher dependency of cassava. None of the 14 clones that occurred in more than one district had only one variety name but eight of them had more than three names. Seven names of the clones in Table 2 were used for more than one clone. One explanation for several names for the same clone could be differences in local languages between farming communities both within and between districts. One probable reason for the occurrence of several clones with the same name could be classification mistakes when new varieties are introduced as indicated in Nkhata Bay (Mkumbira *et al.*, 2003a). Marker analysis shows that the conclusions about

Table 2: Variety names¹ of clones that occurred in more than one district.

District	Genotype of the clone														
	17	19	22	36	37	41	43	46	50	81	114	116	156	160	
Nkhata Bay			102	16	19 20	23	32		29 38 39 40	10 40					
Kasungu Nkhotakota		8 ? ³	11 12		20	22	28		38	11		11			
Salima												51			
Mangochi	7			13 18	21	22 24		36 37				13 46 47	52		
Balaka Machinga				13 13		22 22	31					13 45 49 50	53		
Zomba				13	20	23 28 29 30	22 29 31	13 34	38			13	54	55	
Blantyre Mulanje		9		17 14 15		25 26 27	29	35 33			22 41 42	48			
Thyolo				7		22					43				

¹ A number in the table stands for a variety name

² Numbers in bold indicate that the variety name occurs in more than one clone

³Unknown.

B' and 'Matyenda-1' in Nkatha Bay, and the blocks Chisinga, Milonde and Nande in Mulanje, there was a difference in the use of 'bitter' varieties. In the latter only 10% of the clones were classified as 'bitter' whereas in Nkhata Bay they were as many as 60%.

Distribution of clones. The 623 collected and genotyped plants belonged to 165 locally named varieties and 178 clones. Sixty-six clones were classified as 'appreciated' clones but 112 only occurred on a single farm (Table 1). Of the 'appreciated' clones 48 of 66 (73%) occurred in more than one village. Between the adjacent blocks in Nkatha Bay ('Thowolo-B' and 'Matyenda-1'), and in Mulanje

(Chisinga, Milonde and Nande), the percentage of clones cultivated in more than one block was 43 and 45, respectively. The distribution of the 14 'appreciated' clones that were grown in more than one district is presented in Table 2. Since there is a risk that the markers used do not discriminate among all clones the number of variety names used for a clone could be overestimated and the number of names used for more than one clone could be underestimated.

Relation between clones and local variety names. There was no one-to-one relationship between clones and local variety names. Thus only 22 of the 56 varieties represented by more

Table 3: Number of plants belonging to any of the ten clones in each micro-environment state.

Micro-environment	State	Clone									
		Ch ¹	Mb	Nc	De	Go	Ko	Ng	Nh	Nm	Nk
Anthill	Present	4	12	8	19	19	10	10	6	18	11
	Absent	9	8	7	8	3	2	4	5	2	5
Topography	Upland	10	21	13	20	18	11	7	11	22	9
	Dambo	3	1	2	8	6	3	7	2	.	7
River	Present	7	6	4	12	8	10	2	4	8	8
	Absent	6	16	11	16	16	4	12	9	14	8
Road	Present	5	12	7	20	10	9	4	5	14	9
	Absent	8	10	8	8	14	5	10	8	8	7
Vegetation	Savannah	13	19	12	26	20	14	11	11	21	16
	Woodland	.	3	3	2	4	.	3	2	1	.
Land preparation	Ridges	11	22	13	24	20	12	14	12	16	14
	Mounds	2	.	2	4	4	2	.	1	6	2
Plant age (months)	6 to 9	7	17	10	17	8	7	6	10	13	5
	10 to 15	3	4	3	5	6	2	4	.	5	6
	16 to 20	3	1	2	6	10	5	4	3	4	5
Field age (years)	1 to 2	.	5	3	5	4	2	2	4	6	.
	3 to 4	13	17	12	23	19	12	11	9	16	15
Cropping system	Mono-crop	12	12	12	19	17	9	10	9	14	11
	Inter-crop	1	8	3	8	4	3	3	2	6	4
Farm management	Clean	10	13	13	22	12	6	7	10	12	3
	Weedy	3	7	2	5	9	6	6	1	8	12

¹The two letters refers to the varieties in which these clones dominated in the study site Ch=Chimphuno; Mb=Mbundumali= genotype 41; Nc=Nyachikundi; De=Depwete; Go=Gomani= genotype 50; Ko=Koloweki; Ng=Ng'wenyani; Nh=Nyanhalawa; Nm=Nyamakozo; Nk=Nyankhata.

the diffusion of cassava clones based on occurrence of local names (e.g. Fregene *et al.*, 2000; Otim-Nape *et al.*, 2001; Nweke *et al.*, 1994) could be misleading.

Marker analysis also suggests that two clones that have been chosen for multiplication and distribution by the national program in Malawi, around two decades before this study, have been widely diffused among the farmers. These are the clones with the genotypes 41 and 50, that is the clones of

the varieties 'mbundumali' and 'gomani' in the Uniform Yield Trial kept at the Research station in Makoka. They were also common under these names in Nkatha Bay district and dominated in the two blocks 'Thowolo-B' and 'Matyenda-1' at the time of two earlier studies (Chiwona-Karlton *et al.*, 2000; Mkumbira *et al.*, 2003a). The sweet 'mbundumali', which means 'one cannot finish eating it' in the languages spoken in the area (Chiwona-Karlton *et al.*, 1998), could have been grown

Table 4: Micro-environments with significant effect on root yield components.

Clone	Cyanogenic glucoside	Root weight	Dry matter
All	Land preparation Farm management Anthill	Land preparation Topography Field age	River Land preparation River
All bitter	Land preparation Farm management Field age River	Topography	Land preparation
All cool	Land preparation River	Topography Road	Topography
Chimphuno	Anthill Land preparation Farm management	Farm management	
Mbundumali	River	Cropping system	Road
Nyachikundi	Land preparation	Road	Vegetation Road
Depwete	Land preparation Field age	Land preparation Cropping system Topography Farm management	River
Gomani	Farm management Cropping system Field age	River	Road Farm management
Koloweki	River	Road Field age	Land preparation
N'gwenyani	Farm management		
Nyahalawa	Road		Anthill
Nyamakozo	Land preparation Field age Cropping system	River Field age	
Nyankhata			Topography Cropping system Farm management

there for more than five decades (Chiwona-Karlton pers. com.). 'Gomani', named after the male introducer (Chiwona-Karlton *et al.*, 1998), could also have been grown at least that long in the country. The clone with genotype 41 was represented by most plants in this study (66). It occurred in nine districts

(Table 2) and was the dominant clone in seven varieties. On average 80% of the plants belonging to these varieties belonged to the clone with genotype 41. The study therefore gives evidence that the clone with genotype 41 was widely distributed in a large part of the country, although under different names, and

rarely was mixed up with other clones. However, it is unrealistic to assume that a large fraction of the plants belonging to this clone would be an effect of recent introductions from the national program since the interviews indicate that the variety has been cultivated for decades in many of the villages covered by the study.

It is more probable that the clone, in a majority of the areas, has been multiplied and distributed by the farmers independent of the national program for several decades, an indication that clones can be widely accepted by farmers. Possible reasons for the wide distribution could be its fairly high yields and its relatively wide adaptation, although it does not perform exceptionally well in these respects compared with other local varieties in a nation-wide field test (Mkumbira *et al.*, 2003b). Another reason could be its distinct morphology from other clones. Plants belonging to genotype 50, the bitter clone distributed as 'gomani' in the national program, was, with one exception, called 'gomani' or 'gomani-mfipa' by the farmers. Contrary to the clone with genotype 41, this clone only occurred in three districts (Table 2) but, even for this clone, its wide and dominant occurrence is difficult to explain with a recent introduction by the national program. However, in this case it would also be difficult to explain it as an effect of its distinct morphology considering how it has been shown to overlap with other clones (Mkumbira *et al.*, 2003a) or due to its high and stable productivity (Mkumbira *et al.*, 2003b). The farming communities' capacity to maintain 'gomani' as a single clone is therefore difficult to explain but it indicates that when a variety is important to them the farmers find ways to keep it genetically pure. The take-home lesson seems to be that clones already accepted by farmers have a good chance to be widely distributed.

This study also indicates that farmers' plants should be classified into those that belong to clones evaluated and grown for their production value (a production

population) and those under test or kept for future needs (a breeding population). Thus the interviews corroborate the findings from earlier studies in the two blocks in Nkhata Bay that farmers keep a high genetic diversity, a breeding population, by maintaining old varieties, testing new introductions and use seedlings (Chiwona-Karltun *et al.*, 1998; Mkumbira *et al.*, 2003a). Fregene *et al.* (2003) have also shown that the population structure of locally grown cassava in Africa suggest that the use of seedlings is quite frequent in the development of new material. The observations in the two blocks in Nkhata Bay also imply that the plants belong to many more clones than those found in this study. Thus, as indicated above, 18 plants among those belonging to the ten most commonly grown varieties in the two blocks in Nkhata Bay had unique genotypes, that is belonged to 18 different clones (Mkumbira *et al.*, 2003a). Since the total number of plants of these varieties, among the 176 farmers, could be estimated to have been much over 100 000, the total number of clones could be ten fold of that observed, that is several hundred (Table 1). The number of clones that are grown for their production value on the other hand, is most probably much smaller. Thus, as mentioned above, most of the varieties in these two blocks were recorded and plants from a majority of these were grown by more than one farmer (data not shown). Therefore the number of varieties recorded in these blocks, 45, could be considered the maximum number of clones grown for their production and the number of 'appreciated' clones, 29, a lower limit. Considering that the frequency of plants with dominating clones is higher among the ten common clones in the two blocks (78%) than among the other varieties studied (53%), the fraction of clones used for their production value of the total number of clones would be small even in these areas. Consequently our data suggest that the size of the breeding population, measured in number of clones, is more than five times bigger than the production population.

Untangling non-repeatable GxE. The generally acidic soils, low in almost all soil nutrients and in water holding capacity indicate that the study area, the two blocks 'Thowolo-B' and 'Matyenda-1', was indeed a marginal environment. The results of this study show that microenvironments affect root yield components of cassava clones. However, the effect of each microenvironment varied with clone. Furthermore, the number and composition of microenvironments with a significant contribution varied from one clone to the other (Table 4). This strongly suggests the presence of GxE interaction at a farm level. However, the unbalanced design and the large amount of possible variables analysed did not allow an estimate of the size of effects but only show their significance level.

There were more microenvironments with significant effect on the bitter clones compared to the sweet when analysed as a group. This may be attributed to the difference in total number of observations (sweet, n=50; bitter, n=131). However, genetic difference observed between the 'sweet' and 'bitter' clones may also contribute to this difference (Mkumbira *et al.*, 2003b). Mkumbira *et al.* (1996) also observed a similar trend with cyanogenic glucoside levels measured on the same cassava clones grown at seven different environments in Malawi. They reported that cassava clones with low cyanogenic glucoside levels varied less between agro-ecologies compared to those with high levels.

Both agronomic practices and physical features of the land in farmers' fields were important microenvironments causing GxE interaction (Table 4). For the agronomic practices, like land preparation and field management, it may be possible to minimise GxE interaction by uniformity in agronomic practices done in farmers' fields. However, this is practically impossible for small-scale farmers to achieve considering their physical and socio-economic environment. A possible approach to minimise the GxE would therefore be to select for varieties that can buffer variation in management.

All the physical features of the land were included as being important at least in one clone. However, topography is shown to have significant contribution in seven clones for cyanogenic glucoside content. Thus, the contrast between *dambo* and upland may affect a wide range of clones as opposed to other microenvironments.

Conclusions

Using molecular markers to identify clones shows promise. The possibility to find widely appreciated clones in Malawi is certainly much higher when using markers than when only using local names only. By using the marker to identify the clone the plants growing in the farmers fields can be used for finding microenvironments causing GxE on farming communities.

A necessary requirement to identify clones is a discriminative set of molecular markers. In this study eight SSR markers were used, but to be on the safe side a higher amount is recommended. The evaluation of multiplication and distribution of improved varieties would benefit from molecular marker analysis. Sampling schemes for genetic resources of cassava ought to consider that farmers conduct and maintain production and breeding populations.

The analysis of GxE on the farm level is favoured by using communities where the farmers grow many varieties and where the growing conditions vary but also by considering similar representation of each clone in all environments.

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The use of doubled-haploids in cassava breeding

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Abstract. Cassava breeding is difficult and, compared with other crops, inefficient. The problems in cassava breeding relate to the length of the breeding cycle, the large genetic load present in the crop, and the heterozygous nature of the parents and progenies evaluated. The production of doubled haploids, through tissue culture techniques, offers interesting advantages. By definition, any process that involves increased homozygosity will result in a decrease of genetic load. Doubled-haploid lines, therefore, are expected to produce better hybrids. Furthermore, the availability of homozygous lines would allow for a gradual and consolidated breeding to improve parental performance in hybrid combinations. This means that the genetic enhancement will benefit from previous gains, like steps in a staircase. The breeder “owns” the genetic superiority of an inbred progenitor but that is not necessarily the case with heterozygous parents, particularly in heterozygous crops like cassava. With the introduction of doubled-haploids, the emphasis of cassava breeding shifts from producing large number of hybrids (hoping to find a superior one) to improving parents for the production of better hybrids that are “*designed*”, not just found. In addition to these advantages doubled-haploids will facilitate discovery and exploitation of recessive traits and germplasm conservation. One important additional advantage is that germplasm exchange could be greatly facilitated, thus helping to bridge the relative isolation in which cassava-breeding projects in different countries currently operate.

Introduction

Cassava improvement has not been as consistent and efficient as other crops and has many constraints. A typical scheme implies crossing elite clones to produce segregating families. Each individual produced is highly heterozygous. Once a superior genotype is identified (a process that requires about six years), it is vegetatively multiplied to take advantage of the reproductive habits of this crop (Kawano *et al.*, 1998; Jennings and Iglesias, 2002). This system (except for the vegetative multiplication) is similar to the ones used for autogamous crops (beans, wheat, rice, etc.) as well as for the hybrid maize industry. However, there is a major difference because cassava is never pushed to produce inbred (homozygous) lines from the segregating progenies of a given cross. The system also bears some similarities with recurrent selection used in allogamous crops (maize), but there is a significant difference because in cassava there is not a real population whose allelic frequencies are modified through evaluation and selection, as in true recurrent selection schemes.

The differences described imply that cassava breeding is slow and inefficient. Some of the reasons for this inefficiency are listed below:

- a. Because no inbreeding is carried out at any stage of cassava breeding, a sizeable genetic load (undesirable or deleterious genes) is expected to prevent the crop fully achieving its actual yield potential.

- b. There are no clearly defined populations (as defined by quantitative genetics), allelic frequencies cannot be efficiently modified. Cassava breeding in this regard resembles more the selection of segregating progenies from two parental lines in autogamous crops.
- c. Because the highly heterozygous nature of the crop, dominance effects are likely to play a very important role in the performance of materials being selected. The current scheme can exploit dominance effects because, once an elite clone is identified, it can be propagated vegetatively (therefore carrying along the dominance effects). However, selection of progenitors for the production of new segregating material is based on their performance *per se*. In that case, the current procedure has a bias because the breeding values of these clones are unlikely to be well correlated with their performance, precisely because of the distorting effects of dominance.
- d. Production of recombinant seed is cumbersome in cassava. Only 0.6 viable seeds per pollination are produced. It takes about 16 to 18 months since a given cross is planned until an adequate amount of seed is produced.
- e. When a desirable trait is identified, it is very difficult to transfer it from one genotype to another (even if a single gene controlled the trait). The back-cross scheme, one of the most common, successful and powerful breeding schemes for cultivated crops, is not feasible in cassava, because of the constant heterozygous state used throughout the breeding process.
- f. Maintenance of genetic stocks is expensive and prone to eventual losses through time. The only proven methods for long term storage of germplasm is through tissue culture procedures (expensive and sometimes require several months to recover plants for planting in the field) or else by maintaining representative plants in the field (expensive when large number of genotypes need to be maintained year after year, and also the stocks are vulnerable to gradual contamination of pathogenic and non-pathogenic organisms).
- g. Exchange of germplasm among cassava breeding programs in different countries is very much restricted to a few plants representing few genotypes. Cassava breeding projects, effectively work in very isolated conditions.
- h. Lack of inbreeding in cassava breeding implies that there are very little opportunities for identifying useful recessive traits, which could have huge beneficial effects in the crop. For instance, acyanogenesis in the roots has been identified as a very desirable trait to look for, but so far there has been no success in this regard. It has been postulated that this trait may be recessive. Also worth mentioning are the several starch mutations that generally are recessive in most crops.

These may all be a valid explanation for the limited genetic gains for higher productivity or value observed in the crop, compared with that of other crops such as maize or rice. It should be emphasized that because the highly heterozygous condition of cassava in every stage of the breeding process, consolidation of genetic gains is very difficult, due to the inherent genetic instability of heterozygosity.

From the practical point of view, implementing a traditional recurrent selection method in cassava offers some problems. Pollinations are slow and inefficient. It takes about 16 to 18 months since a given cross is planned until the recombinant seed is finally obtained (usually field operations have to adjust to the occurrence of the rainy season, and if that is the case, then planting can only be done 24 months after planning the cross). The third year would be used to grow the plant from the botanical seed. During the fourth year, a clonal evaluation could finally be carried out. Therefore a typical recurrent

selection method would require no less than four years. In this case, however, no selfing for reducing genetic load would have been included.

A cassava-breeding scheme based on the production of doubled-haploids. This is an article postulating a new approach for cassava breeding, which is in the process of implementation. It has not been applied to any particular breeding population at CIAT at this point.

The advantages of inbreeding. When an elite clone is self-pollinated two important events occur: a) the unique, specific combination of alleles present in the genotype is broken, therefore losing the agronomic superiority that the clone might have. b) self-pollination forces that half of the loci on average to become homozygous, thus facilitating the elimination of undesirable, deleterious alleles present in the original clone but hidden because of the predominant heterozygosity. In other words, selfed progenies allow for a reduction of the genetic load originally present in the clone, therefore becoming better progenitors themselves. In a way, selfing allows to “concentrate” the desirable genes originally present in the elite clone.

If inbreeding was pursued until near or complete homozygosity, then the transfer of desirable traits through the back-cross scheme becomes feasible. Also homozygosity “captures” genetic superiority because of its inherent genetic stability. Therefore each cassava improvement cycle would be a consolidated step that could help further progress in a more consistent and predictable way. On the other hand, each time a hybrid is used as parent, the process goes back to the initial step because of the inherent genetic instability of the heterozygous material. In this case, progress cannot be easily consolidated or sustained through time, but only in a rather inefficient way.

From the quantitative point of view the variability of a given population has traditionally been split into two major

components: additive and dominant effects. Additive effects are very important because they define the breeding value of an individual, that is, its relative merit based on the quality of the progeny they produce. Dominance effects are also very important in plant breeding. They are the main contributors to the heterosis or hybrid vigor observed in hybrid cultivars, including cassava. However, contrary to the additive effects, the dominance cannot be transmitted to the progeny. This means that dominance effects cannot be effectively exploited in a breeding program, unless a sophisticated breeding scheme (reciprocal recurrent selection) is employed.

The current breeding scheme is based on the selection of individual genotypes within half- or full-sib families. Table 1 illustrates how the total genetic variance and its components (additive and dominance effects) are partitioned among and within different types of families. It is clear that all genetic effects will influence the selection of plants from half- or full-sib families. That is, 100% of additive variance and 100% of dominance variance emerge during the selection process (this is so because the breeder selects the best families, and then, the best genotype within the best family). This is a convenient situation because, once a given clone is selected, both the additive and dominance effects determining its good performance can be exploited because of the vegetative reproduction of the crop. The specific combination of genes present in this clone can be maintained unaltered generation after generation, as long as there is only vegetative reproduction.

However, only the additive portion of the total genetic variance can effectively be passed on to a next generation, when the same clone is used as parent in a breeding project. It is important to recognize that the dominance strongly influences the selection of the best clones but has no effect on their breeding value. In other words, dominance effects can be beneficial for the *per se* performance of a clone, but it has a confounding effect of its actual value as progenitor.

Inbreeding is advantageous because it erases the dominance effects from the selection process (Table 1). The resulting inbred lines do not possess any dominance effects, and therefore, there will be no heterosis or hybrid vigor expressing in their performance. That is precisely why inbred lines are inferior, agronomically speaking, compared with the non-inbred cassava materials. A striking feature of the data presented in Table 1 is that inbred lines show twice the additive variance originally present. In other words, when selecting among inbred lines the additive variance originally present (say in a F_1 -hybrid) has been expanded, thus greatly facilitating the selection process of those effects (additive) that are precisely the only ones that define a superior progenitor.

In summary, inbred lines are better material for selecting progenitors because by definition they carry lower levels of genetic load, no confounding dominance effect influence the selection process and because the additive genetic effects are expanded considerably, making the selection much more efficient. Also if a breeding process is based on the use of inbred lines the transfer of valuable traits is greatly facilitated because the back-cross scheme becomes feasible.

The availability of inbred lines in cassava would also benefit other areas in addition to breeding. Genetic and molecular marker analysis would be greatly facilitated if homozygous lines were produced. The only way to maintain germplasm in cassava is either by growing the plants in the field or by

tissue culture. Inbred lines could be maintained and shipped in the form of botanical seed. Phytosanitary problems could be reduced or eliminated if maintenance and/or multiplication of genetic stocks were partially based on botanical seed. Germplasm exchange among the few cassava breeding projects in the world would be greatly facilitated because exchange would be based on botanical seed rather than *in-vitro* plants. Finally, clones could be reproduced by sexual means. Although time – consuming, the first stage of evaluation could be based on many plants produced by the crossing of selected inbred lines. Currently the evaluation process takes three years to reach a stage for selection based in just 30 plants.

The problems of inbreeding. Cassava, being an outcrossed crop, abhors inbreeding and shows severe depression. As was the case of temperate maize in the early 1900s and tropical maize by the 1970s, cassava will need to be improved for its tolerance to inbreeding depression. A few recurrent selection cycles (self-pollinating each elite clone down to the S_2 level, and recombining the surviving progenies) should prepare elite cassava populations for the trauma of total homozygosity.

A recurrent selection involving the production of inbred lines would be difficult to implement because of the length of each cycle of selection. It is estimated that about nine years will be required from the time a group of elite clones are selected until

Table 1: Distribution of additive and dominance genetic variance among and within full-sib and inbred line families.

Type of family	Among families		Among plants within families	
	Additive variance	Dominance variance	Additive variance	Dominance variance
Half-sib family	1/4	0	3/4	1
Full-sib family	1/2	1/4	1/2	3/4
Inbred lines	2	0	0	0

Source: Hallauer and Miranda Fo, 1988; Vencovsky and Barriga, 1992.

recombinant seed from their inbred lines was obtained. Therefore, if a breeding scheme using inbred lines is to be implemented, a way to reduce the time required for each cycle of selection is urgently needed.

Double haploids have been produced for many crops. Upon producing an F_1 plant, tissue culture techniques are applied to the reproductive tissue (typically anther culture). This process produces a haploid tissue that, quite frequently, doubles spontaneously to produce the doubled-haploid tissue, which by definition, is homozygous. There are other alternatives for producing similar materials (i.e. using inter-specific crosses).

If an efficient protocol for the production of doubled-haploids were available, it could be incorporated into the cassava breeding process with the advantages that inbred lines offer as explained above. From the practical point of view the protocol for the production of doubled-haploids would allow shortening the time required to produce hybrids from inbred lines down to three years.

Advantages of a breeding scheme based on inbred cassava lines. As already explained the current breeding scheme utilized for cassava possesses some clear limitations: a) dominance effects confound the selection process for good progenitors; b) the continuous heterozygous state throughout the breeding process makes consolidation of genetic gains nearly impossible; c) large genetic load is maintained in cassava germplasm; d) good performing hybrids are not designed, they are just found (eventually) out of several thousand segregating progenies; e) useful recessive traits remain hidden and, therefore, cannot be properly exploited.

The capacity to produce inbred lines in cassava through the use of a dynamic process allows to drastically change the breeding process: a) the emphasis will shift from producing vast number of hybrids hoping that one (or few) will be genetically superior, towards the production of parental lines that will allow 'to design' outstanding hybrids in

a gradual, consistent fashion; b) genetic loads will be quickly reduced in elite cassava populations; c) for several reasons hybrids produced from inbred lines are always better than hybrids produced from non-inbred progenitors (based on widely known experiences in maize); d) germplasm exchange will be greatly facilitated with obvious advantages for the cassava research community; e) gene exchange will also be greatly facilitated. Currently it is very difficult to transfer one valuable gene from its source into an agronomically superior clone. The availability of inbred lines would make the back-cross scheme feasible for cassava; f) inbred materials are genetically stable, they allow the breeder to capture and efficiently exploit the genetic superiority contained in them, therefore, guaranteeing a sustainable and consistent genetic progress that cannot be observed nowadays; g) once a given combination of inbred lines is found (a good performing hybrid) the hybrid could be produced first from botanical seed, and then by vegetative means. This implies not only a faster multiplication rate but also cleaner genetic stocks (from the phytosanitary point of view).

The dominance effects could also be exploited by identifying those inbred lines that produce greater heterotic (hybrid vigor) effects (Hallauer and Miranda, 1988). Although it is not clear from data currently available, a way to identify potential heterotic combinations would be through the use of molecular markers. At least in theory genetic distance has been linked to the occurrence of hybrid vigor, so biotechnology tools would benefit cassava not only by providing the protocol for the production of doubled haploids, but also as a starting point for defining which crosses should have a priority.

Results

CIAT has begun to implement the ideas described in the previous section through a two-way approach, which simultaneously address the major problems related to the

introduction of inbreeding in cassava breeding (CIAT, 2003a). Each of these two approaches is described below.

Improvement of tolerance to inbreeding in elite cassava germplasm. As stated above, cassava is likely to show strong inbreeding depression. This is, precisely, because of the large genetic load expected to affect most of cassava germplasm. Maize faced a similar situation when it was started to be self-pollinated. However, after a few cycles of recurrent selection (Hallauer and Miranda, 1988; Pandey and Gardner, 1992) maize developed acceptable levels of tolerance to inbreeding. This is what needs to and will be done with elite cassava germplasm.

The scheme to improve tolerance to inbreeding in cassava has begun with the production of S_1 lines from a set of elite germplasm (around 30 elite clones) as well as other clones selected for particular reasons (i.e. MECU72 because of its resistance to white flies). A relatively large number of S_1 lines will be produced from each elite clone (between 100 and 200 lines from each clone). The best 20 % of the S_1 lines from each clone will be selected and self-pollinated again to produce a group of S_2 segregating lines. The best S_2 lines derived from each elite clone will be recombined to recover full vigor within each clonal lineage. This recombination would complete the first cycle of recurrent selection to improve tolerance to inbreeding in cassava. It would require between 4 and 5 years for completion. The product of this first cycle of selection (full vigor clones derived from the crosses among the best S_2 lines from each elite clone) would then be evaluated for agronomic characteristics and then self-pollinated to start a second cycle of recurrent selection to improve tolerance to inbreeding.

The S_2 lines produced at the end of the first cycle of recurrent selection will also be thoroughly evaluated for different agronomic traits in search of useful recessive traits (for example, absence of amylose in the starch of the roots or waxy cassava, acyanogenesis, etc.). If vigorous S_2 lines are found, they may

also be further inbred through additional self-pollinations.

The purpose of this activity is to produce cassava germplasm that will be able to withstand the stress of complete homozygosity on one hand, and search for useful recessive traits on the other.

Development of a tissue culture protocol for the production of doubled-haploid lines. As stated above, the production of completely homozygous cassava lines (> 95% homozygosity) would require between 9 and 10 years. This time requirement is too long if the system is to be adopted in a dynamic and efficient breeding program. The second approach at CIAT is to develop a protocol for the production of doubled-haploid lines through tissue culture techniques. Doubled-haploid lines can be produced within 2 to 3 years, therefore, drastically reducing the time required to reach high levels of homozygosity (which in this particular case would be 100%).

The development of a tissue culture protocol for the production of doubled-haploid lines will take advantage of the experience gained in such endeavors for other crops ranging from maize to tulips (CIAT, 2003b).

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Improving productivity and household incomes of resource-poor farmers: The case of cassava-cowpea intercrop

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Abstract. Intercropping is a widespread practice in tropical developing countries. The cassava-cowpea intercrop system was identified as one of the major four cropping systems in the forest and southern Guinea savanna zones of West and Central Africa. The objectives of the study were to evaluate the relative times of planting cowpea, cowpea row arrangement and cassava variety in cassava/cowpea intercrop in farmers' fields on: (a) the crop productivity of the systems, (b) assess their economic return and (c) identify those suitable for further on-farm demonstrations and transfer to farmers. Cassava/cowpea intercrops were tested on farmers' fields in 2000-2002 in the transition and coastal savannah zones of Ghana for sustained crop productivity and household incomes. An incomplete block design was used to assign a factorial combination of three cassava varieties, two relative times of planting and three row arrangements to farmers' fields. The 1 row Afisiafi cassava or local cassava combined with 2- or 3-rows of Asetenapa cowpea; with Asetenapa planted 4 weeks after cassava were the most productive systems. Productivity (LER) over the sole crops ranged from 41% for Afisiafi to 113% for the local variety. Abasafitaa, Afisiafi and local cassava planted 4 weeks before Asetenapa yielded 41-51%, 67-87% and 109-112% of sole crop, respectively. Asetenapa yielded 20% higher under the local than the improved cassava varieties. Averaged over both years, the 1 row cassava (all varieties)/ 2 rows cowpea with cowpea planted 4 weeks after cassava system gave the highest benefit/cost ratio (2.72-3.56) and net benefits (€2.25

million - €3.35 million) over the other intercrop systems and the sole crops. Sole cowpea gave the lowest benefit/cost ratio (1.50) and net benefits (€627,000.00).

Introduction

Intercropping systems involving root crops and legumes have been important traditional farming systems in the developing tropics, especially West Africa. They have been stable production systems that have achieved a level of productivity satisfying prevailing needs of the smallholder farmers and their families. In a general survey of cropping systems in West and Central Africa from 1988-90, the cassava-cowpea intercrop system was identified as one of the major four cropping systems in the forest and southern Guinea savanna zones (Singh, 1993). In Ghana, it is practiced extensively in the forest-savanna transition, forest and coastal savanna zones. While the cassava serves as the main staple (carbohydrate source), the cowpea provides an inexpensive, affordable source of high quality protein to supplement the starchy-based diets and additional cash benefits. Cowpea may also help improve soil fertility through N₂-fixing, and control erosion and weeds.

The system thus, has a great potential to meet future demands such as sustaining increased food production and contributing highly to food security, reduction of malnutrition, hunger and poverty, and maintenance of soil fertility. However, farmers in these zones generally plant their intercrop crops randomly without any defined row

arrangements, use variable relative planting times and also use low yielding varieties (especially the cassava). This has resulted in lower component crop populations, difficulty in management, low crop yields and overall productivity of the systems. Because traditional cropping systems are not necessarily stagnant, but innovation and change are normal features (Ruthenberg, 1980), the challenge is to accelerate this process while maintaining the benefits inherent in stable systems. The challenge faced by researchers is to improve the yield and overall productivity of the cassava-cowpea intercrop system to provide a unique prospect for alleviating poverty and sustaining the livelihood of the numerous resource-poor farmers practicing it. This demands a good understanding of the agro-economic effects or interactions of the system. It was with the purpose of evaluating alternative management systems that are close to farmers' current practices that a verification trial was initiated. The objectives were to evaluate the relative times of planting cowpea, cowpea row arrangement and cassava variety in cassava/cowpea intercrop in farmers' fields on (a) the productivity of the systems, (b) their economic return and (c) identify those suitable for further on-farm demonstrations.

Materials and Methods

A cassava/cowpea intercrop verification trial was conducted on farmer's fields in the forest, forest-savanna transition and coastal savanna zones of Southern Ghana during the 2000/01 and 2001/02 cropping seasons. The three ecological zones have bimodal pattern of rainfall with major rainy season in April-July and minor rainy season in September-November. The verification was planted in April/May in both seasons at all agro-ecologies. An incomplete-block factorial design was used to assign a combination of (i) *2 relative times of planting cowpea* (i.e. cowpea planted 2 weeks before cassava (WBC) or 4 weeks after cassava (WAC), (ii) *3 cowpea row arrangements* (i.e. 1 row cassava

alternating with 2, 3 or 5 rows of cowpea) and (iii) *3 cassava varieties* (Afisiafi, Abasafitaa and Local (farmer's variety)) to farmers. Afisiafi and Abasafitaa are high branching, improved cassava varieties and mature in 12 months. There were 12 farmers or locations in 2000/01 and 18 farmers in 2001/02. Plot sizes were 12 m long and 3, 4 and 6 m wide for the 2, 3 and 5 rows treatments, respectively. Between row spacing was 50 cm for all intercrops, while within row spacing was 1 m (1 plant/hill) for cassava and 20 cm (2plants/hill) for cowpea. Sole cassava and sole cowpea controls were spaced at 1 m x 1 m (1 plant/hill) and 50 cm x 20 cm (2plants/hill), respectively. The cowpea variety used was 'Asetenapa' (a 60-65 day maturing semi-erect improved variety). Land preparation involved slashing or ploughing. Subsequent weed control was by hand (two weeding for the intercrops and sole cowpea and three or four for sole cassava). Cowpea was protected against insect pests with two applications of Karate 2.5EC (a.i lambda-cyhalothrin 25g/l) at a rate of 600 ml/ha and one application of Cymethoate EC (a.i cypermethrin 35g/l and dimethoate 250g/l) at a rate of 1000 ml/ha.

At maturity, whole plots were harvested. Data were collected on grain and tuber yields of cowpea and cassava. The prices for both inputs and outputs were collected in both seasons from the farmers and local markets. Labour data were recorded from farmers using the "by-day" or tractor (in the case of ploughing) charges at each locality. The range for labour charges among the localities was very small that average charges were calculated for various field operations. Mixed models were used to statistically analyze the productivity (cowpea and cassava yields) using SAS (SAS, 1988). Farmers or sites were treated as random. The land equivalent ratio was calculated to assess the advantages of intercropping. Partial budget analyses were done to calculate the net returns for each treatment and the marginal rate of return (MRR) and to identify the dominated treatments (CIMMYT, 1988). The MRR was calculated as:

$$MRR = (NR_i - NR_j) / (TVC_i - TVC_j)$$

where: NR_i = net revenue for treatment i

NR_j = net revenue for treatment j

TVC_i = total variable cost for treatment i

TVC_j = total variable cost for treatment j

Results and Discussion

Crop yields and productivity. The Afisiafi, Abasafitaa and local cassava varieties yielded 37-84 %, 51-85% and 34-66 % of sole crop yield, respectively, when cowpea was planted two weeks before in both seasons (Figs. 1a and 2a). However, when planted 4 weeks before cowpea, Afisiafi, Abasafitaa and local cassava yielded 52-94 %, 62-83 % and 42-73 % of sole crop yield, respectively. Across all row arrangements and both relative times of planting, the improved cassava varieties

(Abasafitaa and Afisiafi) yielded 100-200 % higher than the local varieties under both sole cropping and intercropping (Figs. 1a, 1d, 2a and 2d). Several other workers have also shown improved cassava varieties to be higher yielding than local ones in intercropping (Hahn et al. 1979; Nweke et al. 1988; Ennin et al., 2001). Nweke et al. (1988) and Ennin et al. (2001), for example, reported that improved cassava varieties yielded 71% and 150 % higher than local ones in intercropping systems, respectively. Generally, all the cassava varieties in cowpea planted 4 weeks after cassava (4WAC)(Figs. 1d and 2d), yielded higher than cassava in cowpea planted 2 weeks before cassava (2WBC) (Figs. 1a and 2a), indicating more competition from the cowpea when it was planted earlier. On the average, all cassava varieties yielded higher when intercropped

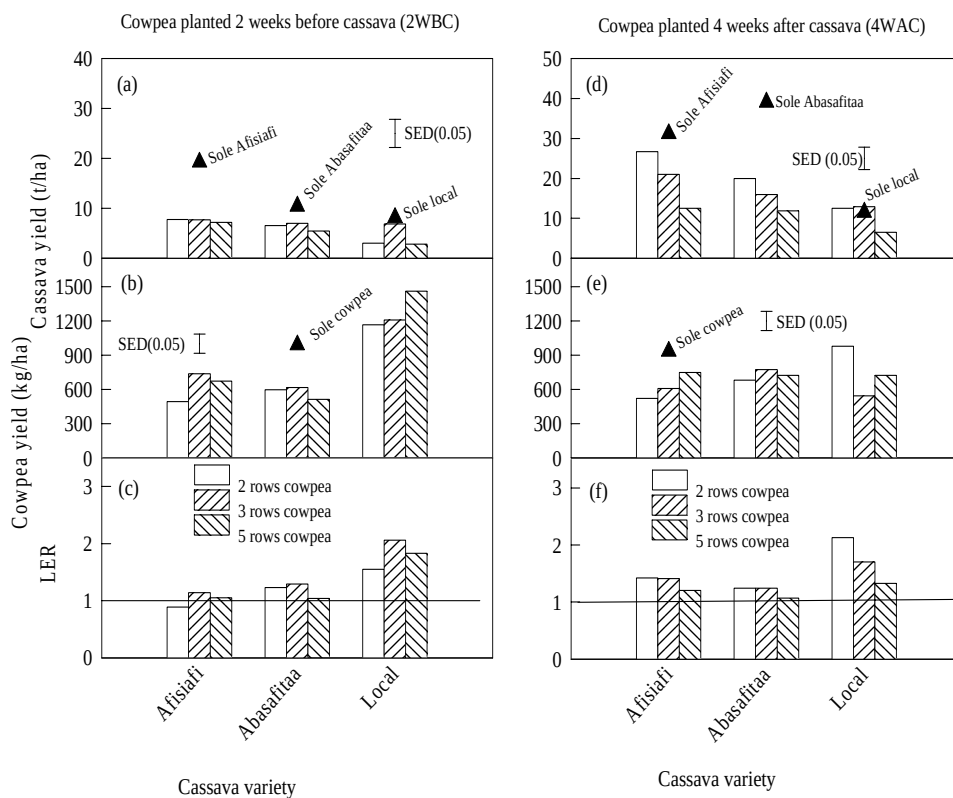


Figure 1: Cassava tuber and cowpea grain yields and LER of a cassava-cowpea intercrop as affected by cassava variety, row arrangement and relative times of planting in the forest, transition and coastal savanna zones of Ghana, 2000/01.

with less rows of cowpea. In 2000/01, cassava yields were particularly low when cowpea was planted 2 weeks before (Fig. 1a). This was due to competition from the cowpea and the inability of cassava to recover faster and fully after cowpea harvest as a result of the intermittent drought conditions experienced in many sites in August-October 2000. In such stress situation, the cassava in more rows of cowpea, yielded equally as cassava in less rows of cowpea, indicating the positive effects of more legume rows through N-fixation, soil moisture, etc, on cassava during the stress periods.

In both seasons, cowpea planted 2 weeks before or 4 weeks after the local cassava variety at any of the row arrangements produced similar or higher yields than sole cowpea (Figs. 1b, 1e, 2b and 2e). Generally, Asetenapa cowpea yielded 20 % higher under

the local variety than the two improved cassava varieties. This can be attributed to the less branching and less competitive ability of the local variety compared to the more aggressive improved varieties (Abasafitaa and Afisiafi). It must, however, be noted that the local varieties differed from farmer to farmer as these were taken from the localities the verification was tested. Between the relative planting times, cowpea planted 2 weeks before any of the cassava varieties did not yield significantly different from cowpea planted 4 WAC (Tables 1 and 2). The slow growth of cassava and the drought experienced in many parts of the country, especially in the 2000/01 season, affecting cassava growth and its competitive ability might have accounted for this. Cowpea yield did not differ among the row arrangements under the improved cassava varieties, when

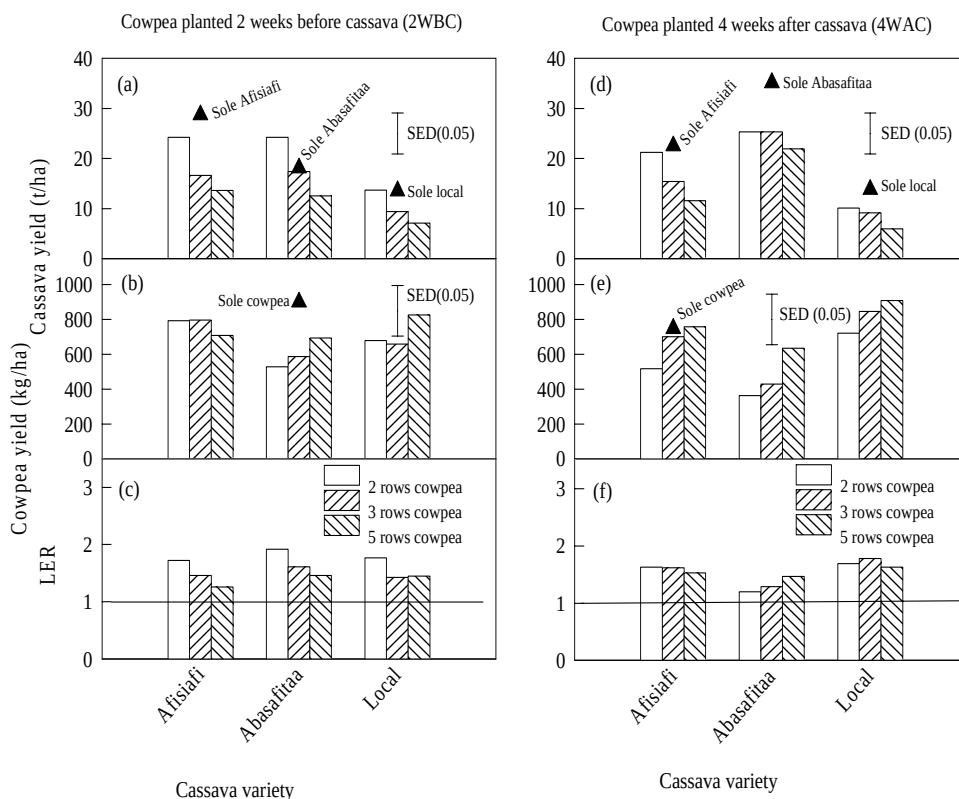


Figure 2: Cassava tuber and cowpea grain yields and LER of a cassava-cowpea intercrop as affected by cassava variety, row arrangement and relative times of planting in the forest, transition and coastal savanna zones of Ghana, 2000/02.

Table 1: A partial budget analysis of Asetenapa planted 4 weeks after Afisiafi under different row arrangements averaged over 2 years in southern Ghana.

	Treatments				
	2 rows	3 rows	5 rows	Sole cowpea	Sole cassava
Gross farm gate benefit from cassava (€ x 10 ³)	3487.12	2651.38	1754.48	-	3907.90
Gross farm gate benefit from cowpea (€ x 10 ³)	1170	1473.75	1698.75	1894.5	-
Total gross farm gate benefits (€ x 10 ³)	4657.12	4125.13	3453.23	1894.5	3907.90
Seed/planting material costs (€ x 10 ³ /ha)	266.6	247	227.4	196	200
Labour costs (€ x 10 ³ /ha) ³	930	930	930	905	1000
Insecticides costs (€ x 10 ³ /ha)	110.6	124.5	138.31	166	0
Total variable input cost (€ x 10 ³)	1307.29	1301.5	1295.71	1267	1200
Net benefit (€ x 10 ³ /ha)	3349.83	2823.63	2157.52	627.5	2707.90
Benefit/Cost ratio	3.56	3.17	2.67	1.50	3.26
Dominance analysis			D	D	
Marginal rate of return (MRR)	102.96 ⁴ 90.8 ⁶	115.04 ⁴			5.98 ⁵

¹ Farm gate price of cassava fresh root yield = €182,000.00/ton. ² Farm gate price of cowpea = 2,500.00/kg.

³ Labour cost for land preparation, planting, weeding, spraying and harvesting. D = Dominated by sole cassava

⁴ MRR of 2 rows and 3 rows over 5 rows. ⁵ MRR of 2 rows over sole cassava. ⁶ MRR of 2 rows over 3 rows.

Table 2: A partial budget analysis of Asetenapa planted 4 weeks after Abasafitaa under different row arrangements averaged over 2 years in southern Ghana.

	Treatments				
	2 rows	3 rows	5 rows	Sole cowpea	Sole cassava
Gross farm gate benefit from cassava (€ x 10 ³) ¹	3297.84	3000.82	2459.18	-	5398.85
Gross farm gate benefit from cowpea (€ x 10 ³) ²	1174.5	1354.5	1527.75	1894.5	-
Total gross farm gate benefits (€ x 10 ³)	4472.34	4355.32	3986.93	1894.5	5398.85
Seed/planting material costs (€ x 10 ³ /ha)	266.6	247	227.4	196	200
Labour costs (€ x 10 ³ /ha) ³	930	930	930	905	1000
Insecticides costs (€ x 10 ³ /ha)	110.6	124.5	138.31	166	0
Total variable input cost (€ x 10 ³)	1307.29	1301.5	1295.71	1267	1200
Net benefit (€ x 10 ³ /ha)	3165.05	3053.82	2691.22	627.50	4198.85
Benefit/Cost ratio	3.42	3.35	3.08	1.50	4.50
Dominance analysis	D	D	D	D	
Marginal rate of return (MRR)	40.92 ⁴ 19.21 ⁵	62.62 ⁴			

¹ Farm gate price of cassava fresh root yield = €182,000.00/ton. ² Farm gate price of cowpea = 2,500.00/kg.

³ Labour cost for land preparation, planting, weeding, spraying and harvesting. D = Dominated by sole cassava

⁴ MRR of 2 rows and 3 rows over 5 rows. ⁵ MRR of 2 rows over 3 rows.

it was planted 2 WBC (Figs. 1b and 2b). However, under the local variety, the 5 rows yielded 21-25 % higher than the 2-rows and 3-rows in both years (Figs. 1b and 2b). When planted 4 WAC, cowpea yields were similar for all row arrangements under all varieties. These results suggest that it may be profitable for a farmer interested in cowpea to adopt the 2- or 3-row instead of the 5-row arrangement, which obviously involved more cost for labour and seed. In addition, more cassava rows or stands on per hectare basis will be harvested in the 2- or 3-row arrangement.

The land equivalent ratio (LER) has been a biological index used to compare the advantages (or productivity) of intercropping over sole cropping (Mead and Willey, 1980). The cassava variety influenced the LER (productivity) of the systems. Although the improved cassava varieties produced higher tuber yields, mean LER values were, on the average, lower than those for the local cassava varieties under either of the relative planting times (Figs 1c, 1f, 2c and 2f). Productivities for both years ranged from 0.89-1.72, 1.04-1.92 and 1.33-2.13 for Afisiafi, Abasafitaa and Local, respectively. Dapaah *et al.* (2003) obtained similar results, where intercrops involving an improved cassava variety "Gblemoduade" had lower mean LER values than those for a local variety "Ankra", despite higher tuber yields. These differences in LER were due mainly to the partial LER contributions of the cowpea crop. Several studies (Fisher, 1977; Francis *et al.*, 1982; Ofori and Stern, 1987) have shown that even though the cereal or root crop components usually contribute a greater proportion of the mixture yield (e.g. about 80 %) (Fisher, 1977), the magnitude of intercropping advantage or efficiency measured in terms of LER follows the trend in the legume yield. Therefore, the inclusion of cowpea in the cassava/cowpea system increases the efficiency of land use and may also improve soil fertility and conserve soil. Some reported gains in land use efficiency of involving legumes in intercrops are 30-52 % for cassava/soybean (Ennin-Kwabia *et al.*, 1993), 20-62 % for maize/

cowpea (Asafu-Agyei *et al.*, 1997; Ennin *et al.*, 1999) and 58-128 % for cassava/maize/cowpea (Ennin *et al.*, 2001). The 1 row Afisiafi or local cassava variety combined with 2 or 3 rows of Asetenapa, with cowpea planted 4 WAC were the most productive systems (Figs. 1f and 2f). Productivities over the sole crops ranged from 41-63 % for Afisiafi and 69-113 % for the local variety. Intercrops involving Abasafitaa gave the lowest LERs (7-47 %). Generally, productivities were higher with the 2 and 3-row arrangements than the 5-row arrangement. Combining the yields of both cassava and cowpea, and their efficiencies of land use (productivities), planting cowpea 4 WAC and at 2- or 3 rows gave higher combined yields of both crops.

Economic analyses. Partial budget analyses were done for only cowpea planted 4 WAC, since that option was more productive in terms of cassava and cowpea component crop yields and land use efficiencies. The economic analyses results, combined over both seasons are shown in Tables 1, 2 and 3. In general, all treatments including the sole crops were economically attractive as they had positive net benefits. Furthermore, the benefit/cost ratios for all, except for sole cowpea and sole local cassava, were greater than 2.0 (Tables 1, 2 and 3).

Results from the analysis for the treatments under Afisiafi showed that 5-rows gave the least benefit/cost ratio and net benefits among the row arrangements (Table 1). The dominance analysis showed that sole Afisiafi had higher net benefit and lower total variable input cost than those of 5-row arrangement and sole Asetenapa. Therefore, 5-row and sole Asetenapa were dominated by sole Afisiafi. The MRR results gave ratios of 102.96 (or 10296 %) between 2 rows and 5 rows (Table 1). Between 2 rows and 3 rows and 2 rows and sole Afisiafi, MRR ratios of 90.8 (908 %) and 5.98 (598 %), respectively were obtained. Adoption of the 2-row arrangement over the 5-row would give an additional gain of ₦9296 for every ₦1000 invested in the process of production.

Table 3: A partial budget analysis of Asetenapa planted 4 weeks after Local under different row arrangements averaged over 2 years in southern Ghana.

	Treatments				
	2 rows	3 rows	5 rows	Sole cowpea	Sole cassava
Gross farm gate benefit from cassava (¢ x 10 ³) ¹	1645.28	1600.14	902.72	-	1844.75
Gross farm gate benefit from cowpea (¢ x 10 ³) ²	1917.00	1566.00	1836.00	1894.50	-
Total gross farm gate benefits (¢ x 10 ³)	3562.28	3166.14	2738.72	1894.50	1844.75
Seed/planting material costs (¢ x 10 ³ /ha)	266.6	247	227.4	196	200
Labour costs (¢ x 10 ³ /ha) ³	930	930	930	905	1000
Insecticides costs (¢ x 10 ³ /ha)	110.6	124.5	138.31	166	0
Total variable input cost (¢ x 10 ³)	1307.29	1301.5	1295.71	1267	1200
Net benefit (¢ x 10 ³ /ha)	2254.99	1864.64	1443.01	627.50	644.75
Benefit/Cost ratio	2.72	2.43	2.11	1.50	1.54
Dominance analysis				D	
Marginal rate of return (MRR)	70.12 ⁴ 67.42 ⁶	72.82 ⁴			15.01 ⁵

¹ Farm gate price of cassava fresh root yield = ¢182,000.00/ton. ² Farm gate price of cowpea = 2,500.00/kg.

³ Labour cost for land preparation, planting, weeding, spraying and harvesting. D = Dominated by sole cassava

⁴ MRR of 2 rows and 3 rows over 5 rows ⁵ MRR of 2 rows over sole cassava. ⁶ MRR of 2 rows over 3 rows

Similarly adopting the 2-row intercropping arrangement over the 3-row or sole cropping would give an additional gain of ¢808 for every ¢1000; or ¢498 for every ¢1000, invested in the process of production. Adopting the 3-rows over the 5-rows gave a MRR of 115.04 (11504 %). The difference between MRR and AMRR were also very high. Therefore, with Afisiafi, the 2-row arrangement is recommended, although the 3-row arrangement was also profitable.

The partial budget analysis for all treatments under Abasafitaa also showed that the 5-row arrangement gave the least net benefit and benefit/cost ratio (Table 2). However, the dominance analysis indicated that sole Abasafitaa dominated all treatments, with the highest net benefit but the lowest TVIC. These results indicate that sole Abasafitaa was more profitable than intercropping with cowpea; and that Abasafitaa does not lend itself well to intercropping due to its lowly place and higher number of branches compared with Afisiafi.

However, if any intercropping is to be done, then the 2-row arrangements is also recommended because it gave higher net benefit, benefit/cost ratio and MRRs of 19.21 (1921 %) and 40.92 (4092 %) over the 3-rows and 5-rows arrangements.

With the local cassava varieties, the results showed they lend themselves very well to intercropping because all the intercropping gave higher net benefits and benefit/cost ratios than the sole cropping, and none of them was dominated by the sole cropping (Table 3). Similar to the results obtained with Afisiafi and Abasafitaa, the 2-row arrangement gave MRR values of 67.42 (6742 %) and 70.12 (7012 %) over the 3-row and 5-row arrangements, respectively.

Conclusion

The productivity and economic analyses indicate that intercropping Asetenapa with Afisiafi or the local cassava varieties, with Asetenapa cowpea planted 4WAC and at 1

row cassava alternating with 2- or 3-rows cowpea are systems recommended for further demonstrations and potential adoption by farmers. These systems, particularly the 1 row cassava alternating with 2 rows cowpea, were not dominated by other systems and also had very high MRR. Discussions with farmers revealed most farmers preferred 1 row cassava/ 2 or 3 rows cowpea based on cowpea and cassava performance and yield. This was confirmed by the analyzed results. However, most indicated higher preference for the 1 row cassava/2 row cowpea over the 3 rows, because of wide spaces left in between cassava rows as a result of failure to follow-up in the minor season with a third crop. In the zones where most farmers are already practicing the cassava/cowpea intercrop system, except that the crops are randomly planted, some have adopted the row planting of either 1 row of cassava with 2 rows or 3 rows cowpea. This system has all the potential for improving and sustaining crop productivity and household incomes and nutrition of the farmers.

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Root and tuber crops and economic growth: The case of Sub-Saharan Africa

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Introduction. Roots and Tuber crop scientists have done a wonderful job of furthering our understanding of root crops in sub-Saharan Africa. Root crops are well known for as 'insurance' crops and safety shields in time of drought and other disturbances, but in recent years, root crops have also become important economic drivers. This new role of root crops is the outcome of having reached the 'take-off' point into commercialization of its products and by-products. The production capacity and markets are such that root crops have moved into being industrial cash crops. This development calls for more investment into basic research, food processing and to better understand of food and labor trends in the larger urban markets of Africa and beyond. To benefit from this exciting development, we need stronger institutional capacities to tackle biological risks (threats) to root crop production such as presently posed by the mosaic and brown streak viruses.

The degree of impact root crops will have on problems of hunger; poverty and development will depend, among other factors, on research choices scientists make and resource allocation decisions by governments and donors on commodity priorities. To date, the disproportionate allocation for cereals research, given its secondary importance in sub-Saharan Africa is difficult to justify.

First of all I would like to express my appreciation for the work that you as roots and tuber crops scientists have been doing to further our understanding of these important commodities and in so doing

contribute to the betterment of millions. Your contributions to the generation of knowledge for development are legendary sometimes spectacular. Time after time, members of this association have come through to help us tackle major challenges in SSA (sub-Saharan Africa).

For us in SSA, root and tuber, from here on root crops, are important foods for humans. Root crops act as our insurance crops and provide safety shields. When it was safe to return to the villages during the devastating war, Sierra Leoneans did not find cereals, but found cassava waiting for them. When the United Nations was conducting a survey of the Southern African famine, they recorded "fields of green" and they turned out to be cassava. Such stories are repeated everywhere. Not so widely known perhaps are the new stories by countries seeking economic drivers. When Ghana's President was looking for an economic driver, he chose cassava. When Nigeria's President was looking for a stimulus to agriculture, he launched a Presidential Initiative on cassava. Whether it is cassava, yam, cocoyam, or sweet potato you are dealing with crops whose significance to the food sector of SSA is paramount.

The overall growth in the production of root crops in Africa (3 percent), versus cereals' (2.5 percent) also reflects its position. This perspective, of root crops as commercial commodities and strong drivers of economic growth is the point of my exchange with you. The commercial value of root crops has long been recognized in parts of Latin America and Asia, but is not yet widely appreciated in SSA.

It behooves us all here to continue, perhaps with an added sense of urgency, to get this message across to the public, governments, and investors. It is our assessment at IITA (International Institute for Tropical Agriculture) that of others that the take-off point into commercialization has now been reached in SSA. By this we mean the production capacity, growth rates, markets and business environments are right and that root crops have moved from being the crops of the poor, to urban foods, to industrial cash crops. We see clear examples from countries like Ghana, Mozambique, Nigeria, Tanzania, Malawi and Uganda. To encourage and nudge this exciting transition along into the commercial stage we may need to change some of our research priorities. We may need more investment in basic research and more attention to food processing, food technologies, and greater understanding of food and labour trends in the larger urban markets of Africa and beyond. We also need to encourage and assist in organizational changes of small producers and processors so that they are not left behind even while stimulating large private sector interests through research on investment potential. Finally, we need to continue to provide, through your research, the kind of investment “guarantees” you have provided in your ability to tackle threats to root crops, such as that now posed by the Cassava Brown Streak. Our inability to address such threats poses a major obstacle on the road to commercialization.

The power of these crops, especially cassava, yam and sweet potato, in our fight against poverty is worth dwelling on. One of our biggest challenge in SSA, of course is poverty. Our people and our governments are poor. In recognition of agriculture’s importance, NEPAD (New Partnership for African Development) encourages SSA governments to allocate a minimum of ten percent of their budget to agriculture. Some governments already do more. Nevertheless, the overall wealth of many governments in SSA is such that, with the exception of the

richest countries, such allocations even if doubled will not be enough. To put this in perspective, the total annual income of the most populous country in Africa is less than that of the fire department of New York City, and half of Singapore’s land transport system (Ogbeh). Some US university budgets are equivalent to the national budgets of many SSA countries. I state these facts to highlight that we are up against incredible odds and to make a difference with so little, great diligence, discipline and careful choices are necessary. It is comforting to see the rich world, and the World Bank, finally return to supporting agriculture and we will of course seek all opportunities to maintain their interest. Unfortunately, wars and natural disasters like drought continue to divert resources from development and agricultural research.

In the absence of any major increases in external sources of support and our own limited resources, we are trying to emphasize a greater reliance on internal strengths and squeeze more immediate solutions out of science. We can do the later by fully appreciating that we do have choices even with the limited funding for science and that the choices we make have implications on how much or how little impact we have on poverty. For SSA, IITA is arguing for greater allocation of resources for root crops and legumes. Investors who support the global research system, including the CGIAR (Consultative Group for International Agricultural Research) and even some national systems in Africa, have and continue to allocate a disproportionate amount of resource to cereals research. For SSA, this historical pattern of resource allocation is difficult to justify in the light of our food needs, current knowledge and sheer prominence of root crops. Like elsewhere in the World, the challenge of reducing poverty in SSA is daunting. To succeed, a complex set of dynamics must work in tandem. This set of dynamics includes the use of different commodities and their products and no single group of commodities has a bigger impact than R&T crops.

Poverty

We talk a lot about poverty so it might be worthwhile to say a few words about it. Just for clarity, we should keep in mind that poverty is omnipresence and is not confined to poor countries. Some OECD countries, which include some of the richest countries in the world, have millions of poor inhabitants. There are varying definitions of poverty but we do not have the luxury to debate the definitions of poverty or even how we measure it. The one-dollar/day measure is now widely used. Irrespective of definitions, we work on the simple fact that **poverty leads to bad outcomes**. Poverty leads to poor health and its associated costs and low productivity. It leads to poor education and wasted minds. Poverty leads to a miserable life and crime and all these outcomes work in tandem to retard progress. There is one important difference between being a poor person in a poor country or a poor person in a rich country in that **poverty in poor countries often has irreversible consequences**. Farmers from poor countries that have been wiped out of farming by a crop disaster are very likely to be themselves lost to agriculture for good.

A child that has missed an educational opportunity probably has missed it forever. Poverty means facing some very tough, normally unacceptable, choices. Resource limitations sometimes force poor societies and their equally poor governments to choose between, for example, educating one group (e.g., children) over another (e.g., adults) or addressing causes of poverty and forsaking those presently in poverty. Another example of a bad outcome is the death of infants. Sadly, about fifty percent of this loss can be attributed just to poor nutrition or the lack of food¹. Here is a critical entry point for ISTRC members in our common search for ways to reduce poverty and we will revisit it.

Poverty and Agriculture

The relation between poverty and agriculture is unfortunately mostly appreciated in

professional circles. This is not sufficient and we need to broaden this appreciation over a wider audience (Schultz). The fact remains that it is difficult to deal with poverty without dealing with agriculture, in particular agricultural productivity and the rural sector as a whole. Even for the urban poor the success of agriculture is vital to them. The relations between poverty and agriculture are, in very large part, rather straightforward. If we aim to improve both rural and urban poverty, we must affect agricultural productivity. Productivity improvements in agriculture lead to increases in food production, which leads to cheaper food. The availability of cheap food carries enormous benefits for poor consumers, which includes both the farmer and the urban poor. This benefit is a direct reduction of their food bill, which normally makes up a very high percentage of their total expenditure. A ten percent reduction in food prices would contribute almost half that or more in increases to the real income of the poor.

The benefits do not stop there because to reduce the cost of food we have to produce more food. As more food is produced and moves from the farms to the urban areas, economic activities, small and big, are generated all along the way in production, collection, grading, storing, transporting, consolidation, processing and resale. These activities create employment and income opportunities for both the rural and urban poor. In addition to the economic benefits, the availability of cheap food, and thus greater access and consumption of food, contributes directly to improved nutrition for the poor. This in turn contributes to better health. At this level of income, more food is good. Access to cheap food often translates to increased food consumption, which improves nutrition, reduces child mortality. These positive outcomes themselves add to economic gains through fewer sick days, higher productivity, and less medical and funeral expenses. In SSA at least, the power of agriculture productivity as a tool for poverty reduction cannot be overstated.

Approaches to Poverty reduction

How does one approach poverty reduction and what role for R&T in such an approach? If we begin at the global level you will notice that the first goal of the **Millennium Development Goals** (MDG) is the eradication of extreme **poverty** and **hunger**. There is a good reason why the words ‘poverty’ and ‘hunger’ are together. We can do a lot about hunger with agriculture. Another powerful fact is that we can also tackle hunger in a way that contributes to reducing poverty. The focus on agricultural and rural sector is very profitable and all the known benefits of a gender positive program: Local production, wealth creation and Risk Reduction: The IITA Approach: In our case at IITA, we approach poverty reduction via three concepts – local production, wealth creation and risk reduction.

Local production

In contributing to poverty reduction and economic growth, we argue for an emphasis on local production. We argue for local production because it is the more stable way of improving livelihoods, of increasing food security, and contributing to more long-term and broad based economic growth in developing countries where the bulk of the poor reside. Within the developing countries, the poor reside mostly in rural areas and derive their livelihood directly or indirectly from agriculture. Producing locally is also another form of providing some slight protection against global market factors. Local production has the added advantage of keeping investments local, which benefits rural development as incomes generated in rural areas tend to be invested locally.

Investing in the rural areas also slows down the rural to urban migration. Once the immigrants get to the urban areas, most become the urban poor. Addressing the urban poor is an even greater challenge, as few know how to deal with it and most interventions directed at the urban are more costly than

those for the rural. “No sector will employ as many people as agriculture. No sector will contribute as much to the gross domestic product and no sector will bring as much stability”. However for this to happen many things need to happen. Our infrastructure is very limiting as are our market information systems.

Countries in SSA, globalization notwithstanding, actually might need to continue depending more on local production any way because what is available does not correspond with what is desired. The exportable foods from the industrialized world include only a few of the commodities we consume in SSA. Food exports from the industrialized world are dominated by cereals and do not, for example, include our favorite root crops on which over a third of SSA depends.

In addition, purchasing foods overseas requires purchasing power and foreign currency, both of which are in short supply. On a longer time horizon, changing food habits in the industrialized countries may translate into a reverse situation where more foods from the developing countries are needed by the industrialized ones, as their consumers demand even more variety from the tropics and elsewhere. Such trends present an opportunity for developing country products, where traditional exports have dropped by more than two-thirds (FAOSTAT). One can already find many types root crop products in cities in the Northern Hemisphere. This bodes well for root crops but there are some challenges ahead.

Wealth creation

We have mentioned the value of producing more food and its effect on both the urban and rural poor. The wealth creation concept is simple. It says take what the poor produce and make it earn more for them. If a farmer sells a root crop product in one form we can help them sell it for slightly more. Simple processing, can improve their income. Commercial processing, of course, improves the incomes of even more people. Nigeria is

aiming to create over a billion dollars per year from economic activity in processing, marketing and foreign currency savings from root crops. In essence such activities help move the commodity and its products into other uses. The degree of impact we have on the poor depends on what choices we make in defining the problems and what research we decide to do. On the other side of the same wealth creation coin are the risks producers face and the need to manage or avoid them. Your continued contribution to this dimension is desperately needed. Adopting this path may imply a slight change in our research to emphasize more processing and food technology.

Risk reduction

The rural sector and the farmer that we depend on to produce the extra food that is needed face many risks. The poorer they are the more limited their ability to deal with these risks. Because the poor live on the edge of life, it does not take much for them to fall off. As mentioned earlier, unlike in the industrialized countries, falling off the edge in poor countries often has irreversible consequences.

The risk reduction strategies of the poor

Helping poor farmers reduce their risks is an effective way to reduce poverty because in spite of incredible effort and creativity on their part, the tools at their disposal are limited. Knowledgeable about climatic risks, for example, poor farmers will not only grow different crops but also grow them in different locations. They also often opt for stability in yields, and less risk thus limiting their income potential. Unfortunately their otherwise excellent strategies, often let them down because they are confined to certain localities, have limited purchasing power, and negative factors affect most of their options simultaneously. Drought, as we saw in the Horn of Africa and in Southern Africa affected

not only the crops they grew but also other agricultural activities in their locality such that employment opportunities which they depend on to diversify their source of income were reduced at the very time they need them most. Drought destroys both crops and livestock. In such adversity, each one affected tries to respond to the drought by selling off their assets – seeds, livestock, and roofing materials from their houses - to buy food. Their “terms of trade”, to borrow from the jargon of economists, deteriorates. Essentially, they compete against themselves not only in bad times but sadly also during good weather as all try to rebuild and restock at the same time and prices rise. Therefore, in good times as in bad, the risk response by the poor is often a costly one. Other factors such as poor infrastructure and lack of information also limit their options. Since the ability of the poor to respond to risks is limited, supplementing their risk-management efforts is a vital strategy to economic growth. What are some of the risks that we talk about? For convenience, while cognizant of their interrelatedness, we have, at IITA, categorized the risks producers and rural communities face, into biological, commercial, natural disasters, and political. I will touch on the first three because the root crops are an important weapon in addressing them.

Biological risks. These come in the form of viruses, fungi, bacteria, pests and weeds. This audience needs no elaboration on these sorts of risks. As an example, today, five or more Eastern African countries, including Tanzania, are suffering the effects of the cassava brown streak virus. These include Mozambique, Zambia, Kenya, and Malawi. National scientists in Mozambique and Tanzania report damage rates of over 50. We do not know much about this virus and while we research it, we can only implement containment plans. In the West and Central Africa, the combination of two virulent virus strains is threatening the very stability of large communities of Nigeria and the food security of several neighbouring countries. Taking

care of these biological risks is truly important. Not only are there severe social costs, but it also avoids substitution, which is in the long term not always for the best. The control of the Cassava Mosaic Virus in Uganda avoided the replacement of cassava by maize, which would have put the farmer in a more precarious position because maize is a far more risky crop for the poor. Controlling these risks pays huge dividends. The control of nematodes in yam has doubled profits and the biological control of cassava mealy bug has resulted in cost benefit ratios of 1:200.

Commercial risks. Perhaps least appreciated, commercial risks can be equally devastating and they come in many forms. As we encourage increased production in order to have cheap foods, we are also exposing the producers to price changes that can ruin them. The familiar price seesaw of high production low prices and vice versa is well known. Actually, we face more surplus problems in Africa than is recognized because they do not get the publicity that food shortages get, but to the producer who has to abandon a year's worth of work and investments it is devastating nonetheless. Today, Nigeria is struggling with its success story of producing enough cassava to cause a severe drop in price. We are working closely with the Government of Nigeria to turn this situation into an important development boost into commercialization. On the other hand, a starch factory near Mombasa - Kenya closed operations in 2001 due to insufficient raw materials and poor processing capacity. We see on the one hand the lack of market access, as being the bottleneck while on the other it is the lack of reliable supplies as the problem. Information and transport systems are not efficient. The accommodation of such commercial risks must be an integral component of the choices we make. Imagine if Nigerian surpluses could be moved economically to feed the capacity in Kenya to Zambia, which is putting out bids for cassava chips. Imagine if we found ways to transform more of these surpluses into high appeal products. One effective way to deal

with the seesaw, once subsistence production is reached, is to move the product into alternative uses. This path has the added advantage of less dependence on policies or a government's ability to intervene in the market. All these challenges have implications on the research you do.

Natural disasters. The cycle of drought that wreaks havoc in Southern Africa is fairly well defined and predictable. We can estimate when the next one will come. A wise person once observed, **"history teaches us nothing, but punishes for not learning its lessons"**

The horrific suffering that the population experienced in Southern Africa during the last drought can be greatly minimized by reducing the dependence on a few crops, barriers to commodity flows, and better infrastructure. The result of the over dependence on maize in Malawi and elsewhere, for example, need not occur and you can do a lot about it since root crops are less moisture sensitive. Farmers themselves are learning fast and correcting the situation. Studies show that as maize production is seen as unreliable, there are significant increases in production and consumption of cassava and sweet potato in Southern Africa in recent years. Production is expanding even in non-traditional growing areas and in cases, ninety percent of the farmers sold their cassava, implying that cassava has become an important cash crop in the region. For more than seventy percent of the farmers, food and cash were the major reasons for growing cassava and sweet potato.

Of the risks I outlined, farmers lump the biological natural disaster risks together and capture them in the word "harvest losses". This is their top concern. Non-biological risks and livestock losses drop to secondary and tertiary levels. These priorities of course vary country by country across SSA, but the aggregate pattern appears representative².

Summary

Root crops are important to our diets and to our poverty reduction efforts. There are

biological, commercial and natural disaster risks to be surmounted and we depend on you to continue directing your research to help the poor address them better. Only if such risks are addressed will our need to produce cheap food and enhance the commercialization phase succeed. IITA and its partners are trying to do their part by breeding increased productivity under similar producer conditions and struggling to provide early warnings to national governments about threats to our food source. Again, we rely on your work to provide the science to tackle such threats. So that the poor can benefit more directly from the full force of your science, we urge the deliberate selection of problem definitions and research methods that reduce risks, and create wealth. We urge the pursuit of research that could help reduce the need for expensive inputs and costly support programs. Bio-control is one example of such a science as are agronomic strategies to improve soils; control weeds and pests, but no doubt there are others. The bio-control programs on mangos and cassava, for example, avoid the need for chemical inputs and its accompanying health factors. For cassava, it even worked in countries that were at war and had dysfunctional governments. Combined with breeding and other national programs, it enabled production of cassava to increase threefold from 11 million tons to over 30 million tons in just ten years. We recognize that such approaches require a lot of research and some long-term commitments and we are trying to raise the awareness for stable financial instruments that could support your work.

To reduce the pain that arise out of natural disaster such as recurs in Southern Africa we are encouraging consumers and governments to broaden the food band to include other crops, in particular root crops but also more legumes, tree crops, fish and livestock. This will reduce their vulnerability and bring other benefits via improved health and reduced costs. To counter the commercial risks outlined earlier we need to double our search for alternative outlets for our products, to

reduce waste at times of plenty, and to construct SSA-wide information systems that will reduce market distortions that generally work against the producers. These thrusts may require that we direct more resources toward more basic research to deal with the biological threats, to increase shelf life, to reduce long growing seasons particularly for yams, and to rapidly enhance product development for root crops that are culturally sensitive. On the nutritional side, we can make progress through many channels, via education, better eating habits such as eating more greens, including cassava and sweet potato leaves, and simply not over cooking them. Over cooking not only denies our families healthier diets, but also uses more fuel. At the other extreme, we can biofortify or fortify them for direct consumption. We can also use root crops to improve human nutrition indirectly via contributing to more productive livestock sector.

A word of caution, we are humans. As humans, we all have our biases. In addition, if that was not enough, we have spent years piling on very strong professional or technical biases. It behoves us all, to avoid the temptation to propose solutions, commodities or techniques because we are familiar with them. To counter such temptations, it might help if we keep the poor we are trying to serve in mind at every step of the way and not let our professional blinders fog our judgment. Every point in our research where we have a choice lets opt of the one that will have the largest and, if possible, immediate impact on reducing poverty. Poverty remember, leads to bad outcomes.

Those of us who are not in the scientific realm, but have to deal with development challenges, are extremely proud of the work you have already done and look forward, with confidence, to even greater contributions from you. On behalf of all the poor all over the world that depend on roots and tubers, on a vibrant agriculture I thank you for your dedication and contributions.

THANK YOU.

Plant water relations and photosynthetic properties of polyploid cassava grown in the Nigerian savanna

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Abstract. Cassava (*Manihot esculenta* Crantz) genotypes of varying ploidy levels (diploid, triploid and tetraploid) were investigated for their plant water relations and photosynthesis to better understand the modalities of selecting for adapted and high yielding genotypes. Data from trials conducted in the savanna agroecological zones of Nigeria were used for this purpose. Anatomy and stomatal morphology showed significant genotypic and ploidy differences. Water use efficiency, stomatal resistance and carbon exchange rates elucidated significant ploidy differences as well as genotypic differences in physiological behavior. Stomatal parameters gave an array of sensitivity and resistance to water deficit stress suggesting desirable selection indices. This paper presents satisfactory and contradictory factors associated with the use of photosynthesis and water relations in an attempt to select for improved productivity in an intensive agroecological zone-based breeding program for cassava.

Introduction

Cassava (*Manihot esculenta* Crantz) is a staple food crop in the tropical Africa. Commonly cultivated by small-scale farmers as a famine-evasive subsistence crop. The potential market for value added cassava remains largely untapped. Although post harvest factors are often cited as bottlenecks for improving value-adding process in many parts of sub-Saharan Africa low yield potential

remains a serious constraint. Commonly grown cassava cultivars are diploids. Data shows low root yields (8 - 14 t ha⁻¹) in farmers' fields with local varieties on marginal soils in South America (El-Sharkawy, 1993) and an overall average yield of 11.9 t ha⁻¹ of storage roots has been reported in sub-Saharan Africa (Nweke *et al.*, 2002). One of the primary objectives of the cassava breeding program at the International Institute of Tropical Agriculture (IITA) has been to improve root yields beyond the current yields on farmers' fields through germplasm improvement and enhancement. Genetic improvement thrust on cassava at IITA, specifically aims at increasing and sustaining cassava production and utilization in sub-Saharan Africa (SSA) through the development, evaluation, and promotion of improved and adapted germplasm for the lowland and mid-altitude agroecological zones. This research is done in collaboration with the National Agricultural Research and Extension systems (NARES) of SSA through informal and formal networking (IITA, 2002).

Through inter-specific crosses of cultivated cassava varieties with their related wild species, as well as by spontaneous polyploidization, polyploid cassava (tetraploids and triploids) clones were isolated at IITA (Hahn *et al.*, 1990). These polyploids were reported as superior to improved diploids with regard to plant vigor and yield potential in preliminary field testing (Hahn *et al.*, 1992; Nassar, 1992). The superiority of polyploid cassava, especially triploids, in terms of yields

offers an opportunity to breed new high yielding cassava varieties (Hahn *et al.*, 1990). However, understanding the physiological basis for such superior performance could assist cassava breeders to precisely target adaptational genes since selection by combining desirable physiological characteristics could increase the efficiency of a cassava breeding program (Ekanayake *et al.*, 2000). An area of major focus in searching for new sources of yield increase has been through enhancing the photosynthetic efficiency of crop plants (Hesketh *et al.*, 1982). Therefore, basic understanding of photosynthesis of polyploids could increase

our understanding of how they achieve productivity gains. Thus the objectives of this study were to evaluate polyploid cassava for their gas exchange characteristics and water relation parameters of physiological significance to improve our understanding of yield performance of polyploids.

Materials and Methods

Field experiment. The experimental sites and trials conducted are given in Table 1. Sites included IITA-Ibadan research farm in derived savanna zone (lat. 7°30'N, long. 3°54'E, altitude 150 mass, mean annual temperature

Table 1: Genotypes used and experimental details.

Experimental Type and Season	Agro-ecological zone	Location	Diploids	Triploids	Tetraploids	Total
<i>Field trials</i>						
1991/92 season	Derived savanna	IITA-Ibadan	TMS 91934, TMS 4(2) 1425	18	7	27
1991/92 season	Southern Guinea savanna	Mokwa	TMS 30572, TMS 4(2) 1425, TMS 63397	7	18	30
1991/92 season	Northern Guinea savanna	Zaria/Samaru	TMS 30572, TMS 4(2) 1425, TMS 63397	7	9	18
PYT (1994/95 season)	Derived savanna	IITA-Ibadan	4 diploid checks			97
1994/96 season & 1995/96 season	Derived savanna	IITA-Ibadan	TMS 30572, Pubscent variant of TMS 4(2) 1425)	TMS 89/00003-10, TMS 89/00003-1	TMS 87/00018-42, TMS 89/00003-4	6
Container experiments 1994/95 season	Derived savanna	IITA-Ibadan	TMS 30572, Pubscent variant of TMS 4(2) 1425)	TMS 89/00003-10, TMS 87/00018-42,	TMS 89/00003-1, TMS 89/00003-4	6
1995/96 season	Derived savanna	IITA-Ibadan	TMS 30572, TMS 4(2) 1425)	TMS 89/00003-1, TMS 84/00316,	TMS 89/00003-10, TMS 81/01623	6
Lab experiments	Derived savanna	IITA-Ibadan	TMS 30572, TMS 4(2) 1425), TMS 91934	2	2	7

PYT – Preliminary yield trial.

28°C, average annual rainfall of 1252 mm, and Ferric luvisol soils); Mokwa in southern Guinea savanna (lat. 9°18'N, long. 5°04'E, altitude 210 m, mean annual temperature 30°C, average annual rainfall of 1232 mm), and Samaru/Zaria (lat. 11°11'N, long. 7°35'E, altitude 686 m, average annual rainfall of 1140 mm, and Ferric luvisol soils) in northern Guinea savanna zone. The experiments were laid out in RCB design with three/four replications. Stem cuttings were planted inclined and 1 m apart on ridges that were spaced at 1 m between-rows. Cuttings that did not sprout were replaced 2 weeks after planting with extra plants that were planted at the same time in adjacent rows. All plots were kept weed-free and sprayed with herbicides when necessary.

Container experiments. In container experiments, stem cuttings were planted inclined in black polyethylene bag/containers filled with 100 kgs of sieved soil (Oxic paleustalf), spaced at 1 m X 1 m and laid out in completely randomized design with four replications. The plastic containers were kept in an open field throughout the growth period (6 months after planting) and regularly watered every two days except when it rained.

Photosynthetic and water relation measurements. Gas exchange characteristics of single attached leaves were made between 3 and 6 months for plants in both container and field experiments. The central lobe of established young fully expanded leaves; 4th - 7th from the top of the branch canopy were enclosed in a 1-L ventilated acrylic plastic photosynthetic chamber of a LI-COR Model 6200 portable photosynthetic system (LI-cor, Lincoln, NE, USA). Measurements were taken during midday between 1100 and 1500h when solar irradiation exceeded $1500 \mu\text{mol m}^{-2} \text{S}^{-1}$ (El-Sharkawy and Cock, 1990). Five measurements were made with a total of 5 leaves per clone from each plot. Immediately following gas exchange measurements, the enclosed leaf was excised and leaf area determined with Li-cor LI-3100 leaf area meter

(LI-COR Ltd., Lincoln, NE, USA) then oven dried to a constant weight for specific leaf weight determination. Porometry was used on same plants as where photosynthesis was measured using Li-cor model 1600 according to protocol described earlier (Ekanayake *et al.*, 1996).

Data analyses. The data were analyzed by analysis of variance (ANOVA) was carried out for each variable and means were separated by least significant difference (LSD) at 0.05 significant level (SAS Institute, 1996). Regression of CER and storage root yield curves were constructed by ploidy level and evaluated for significance with student t-test.

Results and Discussion

Leaf photosynthetic characteristics. Leaf gas exchange rates in container-grown (Table 2) and field-grown plants (Table 3) from the derived savanna zone revealed that triploids had higher carbon exchange rates (CER) than tetraploid cassava clones. CER of triploids in general though were higher than that of the average for diploids did not significantly differ from one of the best adapted and high yielding diploid, TMS 30572 in its optimum environment. Although CER in triploids were higher than the means of the two diploids tested in containers and rainfed field experiments, the CE rates were in the range reported for diploids in other studies (El-Sharkawy *et al.* 1990). In addition, the observed CE rates under sub-optimal growing conditions were lower than its maximal net photosynthetic rates ($40 - 50 \mu\text{mol CO}_2 \text{m}^{-2} \text{s}^{-1}$) for cassava grown in near-optimum conditions with a saturating solar radiation greater than $1800 \mu\text{mol m}^{-2} \text{S}^{-1}$ in photosynthetic active radiation range. In the field, CER values about 27 - 36% lower than those recorded in the container experiment were partly because of stressful conditions (limiting water supply) that prevailed during some of the measurement period. There were great variations in CER among clones of different ploidy levels (Table 3) planted in a preliminary

yield trial (PYT, 1994/1995 season, Table 1) in the derived savanna zone. The CER values ranged from 5 - 15 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for most diploids, 21 - 30 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for triploids, and 16 - 20 $\mu\text{mol m}^{-2} \text{s}^{-1}$ for tetraploids. It was noteworthy that about 13.5% of the diploids tested were in the range of higher CER (21 - 30 $\mu\text{mol m}^{-2} \text{s}^{-1}$) suggesting that it is possible to improve on CER at this higher range by selecting suitable polyploids. More importantly this analysis suggested that not

all polyploids were superior to diploids while the potential for use of triploids based on CER is interesting. It was apparent that there were some desirable genes in diploid cassava, which breeders could continue to extract to step-up productivity. Triploids had the highest fresh storage root yields (Table 4).

Positive correlations were observed between CER and fresh storage root yield ($R = 0.787$; $n = 95$) across all genotypes of different ploidy levels established in the PYT

Table 2: Comparative leaf photosynthetic gas exchange data and water use efficiency values for cassava genotypes of various ploidy levels when grown in containers (1994/95 and 1995/96 seasons).

Genotype §	Carbon exchange rate (CER)(mmol $\text{CO}_2 \text{ m}^{-2} \text{s}^{-1}$)	Stomatal conductance (g)(mol $\text{H}_2\text{O m}^{-2} \text{s}^{-1}$)	Water use efficiency (WUE) (mmol $\text{CO}_2 \text{ mol}^{-1} \text{H}_2\text{O}$)
<i>1994/95 season</i>			
Diploids			
TMS 30572	27.93	2.29	12.21
TMS 4(2)1425P	19.30	1.76	10.99
Triploids			
TMS 89/00003-1	27.75	2.30	12.03
TMS 89/00003-10	27.30	2.21	12.35
Tetraploids			
TMS 87/00018-42	22.68	2.25	10.08
TMS 89/00003-4	20.05	2.29	8.88
Clone mean	24.17	2.18	11.09
LSD (0.05)	4.36	NS	3.32
<i>1995/96 season</i>			
Diploids			
TMS 30572	28.64	3.08	10.38
TMS 4(2)1425P	22.20	1.83	12.10
Triploids			
TMS 89/00003-1	31.15	7.56	6.79
TMS 89/00003-10	30.00	17.50	2.75
Tetraploids			
TMS 84/00316	17.77	2.34	8.22
TMS 81/01623	20.63	5.13	6.53
Clone mean	25.10	6.20	7.80
LSD (0.05)	3.40	10.1	7.05

§ Diploids are currently commonly grown cultivars across West African countries.

trial (1994/1995 season data) of the breeding program. Linear regression equation for storage root yield (t ha⁻¹; Y) was $Y = 6.7336 + 1.2443X$, where X was CER ($\mu\text{mol}^{-2}\text{s}^{-1}$). These

results suggest that high yield cassava could be selected in early stages of the conventional breeding cycle through screening for high CER. This observation is in agreement with

Table 3: Comparative leaf photosynthetic gas exchange data for cassava genotypes of various ploidy levels when grown in the field (1994/95 season).

Genotype §	Carbon exchange rate (CER)(mmol CO ₂ m ⁻² s ⁻¹)	Stomatal conductance (g)(mol H ₂ O m ⁻² s ⁻¹)	Water use efficiency (WUE) (mmol CO ₂ mol ⁻¹ H ₂ O)
Diploids			
TMS 30572	17.77	0.79	22.49
TMS 4(2)1425P	13.13	0.86	15.27
Triploids			
TMS 89/00003-1	16.94	0.73	23.21
TMS 89/00003-10	18.03	0.69	26.13
Tetraploids			
TMS 87/00018-42	15.39	0.69	22.30
TMS 89/00003-4	14.48	0.74	19.57
Genotype mean	15.96	0.75	21.50
LSD (0.05)	3.66	NS	2.32

§ Diploids are currently commonly grown cultivars across West African countries.

Table 4: Average fresh storage root yield (t ha⁻¹) of field-grown cassava genotypes (1994/95 season).

Genotype §	Storage root no plant ⁻¹	Storage root yield (t ha ⁻¹)
Diploids		
TMS 30572	6.9	30.3
TMS 4(2)1425P	8.5	29.0
Triploids		
TMS 89/00003-10	7.6	35.4
TMS 89/00003-1	6.7	32.7
Tetraploids		
TMS 87/00018-42	6.9	22.9
TMS S89/00003-4	4.3	24.1
Genotype mean	6.82	29.07
LSD (0.05)	1.9	8.2

§ Diploids are currently commonly grown cultivars across West African countries.

reported positive correlations of photosynthesis and root yield in cassava diploids only (El Sharkawy *et al.*, 1990) and suggested that high yielding cassava could be selected through photosynthesis measurements if light interception is not limiting. The potential to use C-cycle enzymes and biotechnological tools to step-up the photosynthetic productivity in cassava using triploids is an area that is under-exploited.

Leaf morphology and anatomy. Anatomy and morphology of stomata based on specific leaf weight (SLW), leaf palisade thickness, and stomatal density on the adaxial and abaxial surfaces of leaves showed significant ploidy and genotypic differences (Table 5). The SLW of tetraploids was 26% larger than the diploids while triploids had intermediate SLA values. Concurrently tetraploids also had thicker leaf palisade layers than the diploids and triploids tested. Stomatal density was highest in the diploids as compared with the higher ploidy levels. Data clearly indicated intermediate leaf

morpho-anatomy of the triploid cassava that also contributed to its superior water relation ability as presented in the next section, although significant regression relationships could not be constructed.

Leaf water relations. There were significant seasonal differences in WUE of container-grown plants irrespective of the ploidy level or genotype (Table 2). Significant genotypic differences were observed across all ploidy levels and among various triploids and tetraploids in the field (Table 3) as well as in container-grown plants (Table 3) for leaf water use efficiency trait. In the derived savanna site triploids were 30.7% better than diploids and 17.8% better than tetraploids for WUE. Nevertheless within ploidy groups there were individuals better in WUE than triploids. Leaf stomatal conductances across ploidy groups however were not significantly different (Table 2 and 3) except in one instance (Table 2). Leaf diffusive resistance and transpiration rates were notably higher irrespective of the

Table 5: Leaf morphological and anatomical traits of cassava genotypes of various ploidy levels.

Genotype	Specific leaf weight (mg cm ⁻²)	Leaf palisade thickness (μm)	Stomatal density (no mm ⁻²) §	
			Adaxial leaf surface	Abaxial leaf surface
Diploids				
TMS 30572	5.33	66.00	61.0	615.0
TMS 4(2)1425P	4.33	55.89	61.0	586.0
Triploids				
TMS 89/00003-1	5.10	67.60	40.0	551.0
TMS 89/00003-10	5.48	66.70	39.0	542.0
Tetraploids				
TMS 84/00316	6.08	69.50	37.0	345.0
TMS 81/01623	6.15	79.80	33.6	393.0
Clone mean	5.40	67.58	45.30	505.2
LSD (0.05)	0.61	-	10.6	104.0

§ Measured on adaxial surface of leaves at the veins.

Table 6: Leaf water relation traits (mean $\pm$ s.e.) of cassava genotypes of various ploidy levels using porometry as affected by agroecological zone.

No. of genotypes	Ploidy level	Diffusive resistance(s cm ⁻¹)	Transpiration (μ g cm ⁻² s ⁻¹)	Leaf Temperature (°C)
<i>IITA-Ibadan (Derived savanna)</i>				
2	2x	2.14 $\pm$ 0.11	7.26 $\pm$ 0.01	33.14 $\pm$ 0.33
18	3x	3.90 $\pm$ 0.90	5.27 $\pm$ 0.96	33.06 $\pm$ 0.22
7	4x	3.61 $\pm$ 0.86	4.94 $\pm$ 1.38	33.06 $\pm$ 0.17
Mean		3.21	5.82	33.13
<i>Mokwa (Southern Guinea savanna)</i>				
3	2x	7.38 $\pm$ 0.25	7.61 $\pm$ 0.32	-
7	3x	8.82 $\pm$ 0.34	7.11 $\pm$ 0.13	-
18	4x	8.16 $\pm$ 0.56	7.07 $\pm$ 0.21	-
Mean		8.12	7.26	-

Denotes data not available; measured at midday.

ploidy level in the southern Guinea savanna site as compared to the derived savanna site (Table 6). Similarly triploids had higher resistances than diploids or tetraploids suggesting their comparatively better adaptation to the Guinea savanna. At both locations transpiration rates were high indicating non-water stress conditions at the time of measurement. According to these experimental data, higher ploidy levels (especially tetraploids) did not necessarily indicate better water relation and adaptation characteristics to drought-prone savanna agroecologies. WUE of triploids were also better than diploids as reported in the same ecology in previous reports (Ekanayake *et al.*, 1996; Ekanayake and Githunguri, 2000).

Conclusions

In conclusion, inter-specific hybridization and spontaneous polyploidization have resulted in the production of polyploids with favorable physiological traits (photosynthesis and water use). These promise higher yield levels than the potential productivity of present generation of diploids cultivated across SSA.

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Screening of local cassava varieties against cassava mosaic disease and cassava green mite

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Abstract. One of the sustainable solutions in controlling cassava mosaic disease (CMD) is the deployment of resistant genotypes. In this study, fifty cassava varieties mostly local landraces collected from the Lake Zone were screened for resistance to CMD and CGM. The varieties were evaluated in high disease pressure areas of Geita district in a randomized complete block design in two replications in two seasons. Cassava genotypes were obtained from the cassava germplasm bank at ARI Ukiriguru and were planted at a spacing of 1.0m x 1.0m in plots measuring 10.0m x 2.0m. Disease incidence and severity were taken at three months intervals. In the first year, 40% of the genotypes were severely infected by the disease. Many of these were therefore eliminated. The varieties that were retained exhibited significant differences in disease levels ($P < 0.05$). The most resistant varieties were Kachaga and Lwamilembe. Their CMD severity scores were 1.5 and 1.0, respectively. Root yield for the two varieties were 10.1kg/plot and 6.2kg/plot, respectively. These yields were higher than those of the rest of the varieties. Varieties that had high CMD severities also gave low root yields. The varieties Kachaga and Lwamilembe were therefore recommended for areas with heavy CMD infection.

Introduction

Cassava (*Manihot esculenta*) is an important subsistence food crop in Tanzania especially in the semi-arid areas. The crop is important because it tolerates drought and marginal soil conditions. It is therefore a household

security crop and a famine reserve. Cassava is cultivated and produced in all regions of Tanzania but is mainly produced in Mwanza, Mara, Kigoma, Mtwara, Lindi, Tanga, Ruvuma and the coastal region. Cassava mosaic disease (CMD) and the cassava green mite (CGM) are very big constraints to the production of cassava in Tanzania.

Varieties identified earlier as being resistant to CMD have since become susceptible while those that are resistant to the green mite give low yields and their quality is not acceptable. From recent surveys, CMD and CGM are still pests of economic importance in the lake zone and need immediate attention.

The threat to cassava production posed by the CMD pandemic. In East Africa cassava mosaic disease has been known for a very long time although with limited impact on cassava production. Since the late 1980s, however, the situation changed dramatically with an epidemic of unusual severe CMD, initially reported from north-central Uganda. It is now established that this pandemic is associated with the ACMV variant known as the Ug-V. It has since expanded to cover an area over 750,000 square kilometers of East and Central Africa with devastating effects on cassava production in the affected zones. The disease spread into western Kenya, southern Sudan, eastern DRC and north-western Tanzania, making it arguably the greatest single threat to staple food production in the sub-region. Losses in Uganda between 1992 and 1997 were estimated at USD 60 million per year. Losses

of a comparable magnitude are currently being recorded in western Kenya and northwestern Tanzania. Virtually all of the locally available varieties are susceptible to CMD and many farmers have abandoned cassava cultivation. The effects of CMD have been exacerbated by concurrent infestations with other pests, most notably the cassava green spider mite (CGM). Biological control programs executed by IITA and NARS partners in the region, however, have continued to be successful in managing the effects of CGM but gains from this work are being wiped out by the severe CMD in the region.

Monitoring and diagnostic surveys in 1990 indicated the presence of UgV in four districts of Kagera, where the incidences of the disease were very high. In a 2000 survey the disease was noted to cover Kagera and part of Mwanza regions (Jeremiah and Ndunguru, 1999). Ukerewe Island was also found to be one of the risk areas in the Lake zone. From the experience from the affected areas it was evident that most, if not all local varieties, were susceptible to severe mosaic.

A survey of the districts of Mara and Mwanza regions by Jeremiah and Ndunguru (1999) indicated the presence of good (vigorously growing, high yielding and quick maturing and well adapted) local cassava cultivars. There was however need to establish their levels of CMD and CGM resistance in preparation for the eminent arrival of the epidemic in this area.

Materials and Methods

The materials for evaluation were collected in the areas where severe CMD was not present. The materials had good performance in different aspects including low levels of CMD, high yields and popular with farmers. They were collected from Mara, Mwanza and Shinyanga regions. The materials were put into a trial in Butundwe, Geita district, an area with high CMD and CGM pressure in a traditional cassava growing area that had been affected by the CMD pandemic. The varieties were arranged in a randomised

complete block design, with three replicates. Alleys three metres wide separated the blocks. Single row plots with ten plants spaced 1 m were used.

Fifty (50) commonly grown local cassava cultivars were evaluated. During the first season of evaluation, 17 of these were eliminated due to their severe damage by CMD. Butundwe site in Geita District had high CMD and CGM pressure.

Data Collection. Data collected included CMD and CGM severity starting one month after planting and recorded monthly on every plant thereafter. A scale of 1-5 was used for scoring severity of CMD and CGM where 1 indicated no disease and class 5 severe mosaic disease and leaves severely reduced. The mean severity score for each cultivar was then calculated.

Results and Discussions

Cassava Mosaic Disease and Green mite damage. The mean CMD reaction for the tested clones for three seasons and two locations is presented in Table 1. Varieties Kachaga (1.5), Kachongoma (1.9) Lumala (1.8) and Lwamilembe (1.0) had the least CMD damage at both location and for all three seasons. Varieties Mwendo wa nzige, 77009/5, Ex-Musoma and UKG 95/306 were the most susceptible.

Most of the varieties were affected by the cassava greenmite, although damage levels varied among them (Table 1). Variety Mwita Machela, Kachongoma and 79022 had the least CGM damage. A significant difference was noted among varieties and location. In general, CGM severity was low with a trial mean score of just 2.5.

Cassava yield. The yields of the tested varieties across season and locations are also presented in Table 1. Highest tuber yield was recorded in variety Kachaga (10.1 Kg/plot) followed by variety Lwamilembe (6.2 Kg/plot). The lowest yield was recorded from

Table 1: Cassava mosaic disease, green mite severity and yields for tested varieties.

Variety	CMD severity	Green mite severity	Yield
Monfera	3.1	2.2*	5.4
Kachanga	15	2.1*	10.1
Mbega	2.5	2.9	3.9
Rangimbili	2.5	2.8	3.2
UKG 95/272	2.6	2.3*	5.8
77009/5	3.7	2.5	4.6
Lugomantenga	2.6	2.7	2.9
Kachangisi	2.7	2.1*	5.5
Ex-Ukerewe	2.8	2.2*	3.3
Mlalu	3.3	2.6	6.0
Britis/5	2.4	2.9	3.3
1660/2	2.8	2.9	4.3
Kirigiri	2.5	2.6	4.7
Ali Mtumba	2.8	2.5	4.7
Kachongoma	1.9	1.9	6.0
Obaradak	2.3	2.1*	4.0
Kabumba	2.2	2.7	4.5
Mwendo wa nzige	4.2	2.8	3.5
Nyaikizu	2.6	2.6	6.0
Kihonyi	3.0	2.9	3.2
Sudhe	2.5	2.7	6.0
Mwita Machela	2.5	1.9	6.0
Mzimbitali	3.2	2.4	3.2
Rwabuhaya	3.0	2.4	3.6
UKG 95/277	3.1	2.5	2.3
Ex-Musoma	3.7	2.2*	6.0
Lumala	1.8	2.5	5.6
UKG 95/306	3.6	2.9	5.4
Nyalukapndo	2.9	2.6	3.2
Kamo	3.3	2.4	3.4
79022	2.7	1.7	5.7
Kongolo	2.8	2.7	4.9
Lwamilembe	1.5	2.6	6.2
Mean	2.7	2.4	5.5
CV	27.7	24.7	67.5

variety UKG 95/277 (2.3 t/ha). Seventeen varieties had yields above the trial mean.

A significant difference was recorded among varieties ($P \geq 0.05$). Location and season had a significant influence on yields of the tested varieties. There was also high and significant interaction between location and varieties. A negative relationship between both cassava mosaic disease damage levels ($r = -0.366$), cassava green mite damage levels ($r = -0.33$) and yield was recorded.

Recommendations

Varieties with good levels of CMD resistance have been identified. The most outstanding were Kachaga, Lumala and Kachongoma. The high disease pressure was related to yield reduction with most of the heavily infected varieties having low yields. Fortunately these varieties had low CGM damage scores.

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Breeding cassava for brown streak resistance: Regional cassava variety development strategy based on farmer and consumer preferences

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Abstract. Cassava is an important food crop in the East African coastal lowlands. However, yields are low due to various reasons amongst which are pests and diseases. Cassava brown streak virus disease (CBSD) is one of the major diseases of economic importance in Kenya, Tanzania, Mozambique and Malawi. Yield losses attributed to CBSD ranging from 49 – 74% have recently been reported in some coastal areas of Tanzania. It is estimated that in Tanzania alone, CBSD causes economic losses of more than USD 16,000,000 annually. The wide adoption of resistant varieties is the best sustainable control strategy. However, only a hand full of resistant/tolerant varieties is available in each of the severely affected countries. In order to increase the number of resistant varieties available to farmers, a seedling nursery was raised at Kibaha, Tanzania. About 513 seedlings were selected and cloned for further evaluation. At Kibaha, CBSD disease pressure and spread was very high therefore, 88% of the harvested seedlings were infected. This indicated that this site was ideal for screening cassava genotypes for resistance to CBSD. Although the vector is still unknown, it was very active and infective at this site. Because the seedlings were raised from botanical seeds, ruling out the chance of vegetative plant material transmission,

these results prove that vector transmission can account for a large percentage of plants infected in a field. Families with a high percentage of number of seedlings selected (PNSS) included Kiroba, 71762 and I88/00188. The importance of marking diseased seedlings during the growing season is discussed. Furthermore, massive introduction of germplasm through open quarantine, the establishment of crossing blocks to generate improved genotypes and the use of a decentralized participatory evaluation procedure have been initiated as important strategies towards availing farmers with a wider choice of improved varieties.

Introduction

Cassava (*Manihot esculenta* Crantz) is an important food crop in the East African coastal lowlands. As a food security and famine reserve crop, it is produced mainly through subsistence farming with use of low inputs, rudimentary technology, large post-harvest losses and minimal processing. Excluding Uganda, cassava yields in all the countries of Eastern and Southern Africa are lower than the world's average, estimated at 10.5 MT per hectare (FAO 2001). The major causes for the low yields are: pests and diseases, poor

agronomic practices, poor soil fertility, drought and use of cultivars with poor genetic potential. The major pests are cassava green mites and termites. However, mealybugs, variegated grasshoppers and white scales can sporadically cause serious damage in some parts of these countries. The major diseases are cassava mosaic disease (CMD), cassava brown streak disease (CBSD) and cassava bacterial blight (CBB).

CBSD first reported from Amani, Tanzania in 1936, (Nichols, 1950) is now considered to be one of the major biotic constraints to cassava production especially in the coastal lowlands of Eastern and Southern Africa (Mahungu *et al.*, 1999). Seriously affected countries are Kenya, Tanzania, Mozambique and Malawi. An *Ipomovirus* of the family *Potyviridae* (Hillocks and Thresh, 1998) whose vector is yet to be positively identified causes CBSD. However, because cassava is normally vegetatively propagated, the use of infected cuttings readily introduces the disease into newly planted areas. CBSD reduces total yields as well as rendering the roots useless for human consumption due to the necrosis it causes to the starch storage tissues (Hillocks *et al.*, 2001). Yield losses ranging from 49 – 74% have recently been reported in some coastal districts of Tanzania (Muhanna and Mtunda, 2002). The coastal lowlands of Tanzania contribute to about 50% of the national annual cassava production, estimated at 5,650,000 MT (FAO, 2001). Taking a conservative average yield loss estimate of about 40%, CBSD causes annual economic losses amounting to USD 16,500,000 (price of fresh cassava estimated at USD 15 per MT). The figures will be higher for Mozambique, where the disease has in recent years become very devastating and thus seriously threatening household food security in the three major cassava producing provinces of Nampula, Zambezia and Cabo Delgado.

Early workers in East Africa appreciated the use of resistant varieties for the control of both CMD and CBSD. Breeding for resistance to CBSD went hand in hand with breeding for

resistance to CMD, which started at Amani, Tanga (Tanzania) in the 1930s. The wide variability in susceptibility to CBSVD was observed to be a varietal characteristic and therefore presumably genetic. Their efforts led to the development of resistant varieties popularly known as the Amani hybrids. Intraspecific crosses among the few varieties, which possessed some resistance to CMD, resulted in successful hybrids. However, few of the varieties possessed resistance to CBSD except *Aipin Valenca*. *Macaxeira Aipin*, though susceptible, contributed factors for CBSD resistance, which were evident in the progeny (Jennings, 1957). F1 interspecific hybrids produced from the cross *Manihot glaziovii* (Ceara rubber) x cassava although tree like, were however, mildly infected by CMD in field trials. In the first backcross to cassava, improved resistance to CMD was achieved and one clone in particular, No. 4032, remained free from both CMD and CBSD when tested in a field trial and by grafting (Jennings, 1957). Hybrids from subsequent crosses proved to be the most promising agronomically, and therefore were the most widely distributed (Jennings, 1957). Many of IITA's most popular varieties (including TMS 30572, TMS 4 (2) 1425) were developed with a CMD resistant clone (58308) as one of their parents. This clone was a selection from third backcross derivatives of the interspecific cross between cassava and ceara rubber from Nichol's work at Amani, in the 1940s (Asiedu *et al.*, 1994).

Correlation between morphological traits and resistance to CBSD has been investigated by a few researchers but has not been detected (Nichols, 1947; Mahungu *et al.*, 1999). However, there is mounting evidence that it might be associated with the zigzag stem habit (Kanju *et al.*, 2003).

Some of the present day so-called "local cultivars" especially in Tanzania could have been distributed from Amani (Mahungu *et al.*, 1999), more especially the few which have proved to be tolerant/resistant to CBSD (*Kigoma Mafia*, *Kiroba*, *Namikonga*, and *Kitumbua*) and CMD (*Kibaha*, *Namikonga*

and *Kitumbua*). In each of the seriously affected countries, only a few cultivars have been identified to be tolerant/resistant to CBSD. These are: Kiroba, Nanchinyaya, Kigoma Mafia, NDL 90/134, Kitumbua, Namikonga (Tanzania); Nikwaha, Mulaleia, Chigoma Mafia, Nachinyaya, Likonde, Macia 1, MZ 89/001, MZ 89/105, MZ 89/186, and MZ 89/192 (Mozambique); Kaleso and Guzo (Kenya); CH 92/077 and CH 92/112 (Malawi).

When resistant varieties are not available, tolerant varieties are the best option especially if disease-free planting material can be availed from isolated multiplication plots where crop hygiene is practiced. This is the short-term control strategy being implemented in both Tanzania and Mozambique. These are now being multiplied for wide distribution in the respective countries. The dangers of growing genetically uniform cultivars over wide areas cannot be overemphasized. Moreover, resource-poor farmers in unfavourable environments are credited for maintaining and managing crop genetic diversity. This diversity is of two types: First is the agromorphological diversity which is largely in response to use and preferences, e.g. colours, flavours, plant architecture and crop types. Second is the diversity in terms of a crop's adaptive characteristics, e.g. adaptation to microenvironments, environmental stresses or biological hazards such as pests (Eyzaguirre and Iwanaga, 1996). This project was therefore initiated to contribute to addressing the above two mentioned issues. The project's objective was therefore to develop new cassava varieties which combines multiple resistance to economic important diseases and pests, with farmers'/consumers' preferred traits. Consequently, farmers in the CBSD affected countries will have access to a wider range of improved cassava varieties.

Materials and Methods

Seedling trial. During the 2001/2002 planting season, a seedling nursery was established at the Sugarcane Agricultural Research Institute (SARI), Kibaha, Tanzania. The

seedlings belonged to 124 open-pollinated families of which 119 were from IITA Ibadan, four were from Malawi and one was from the local CBSD tolerant cultivar, *Kiroba*. Seedlings were spaced at 50 cm between and within rows in the field. Diseases and pests were monitored at three-month intervals. Seedlings showing disease symptoms were painted on their stems using waterproof paint. Different colours were used for different diseases. Harvesting was done 12 months after planting (MAP).

At harvest seedlings among each family that were painted red (CBSD symptoms) were heaped together, and those not red painted (no CBSD symptoms) were heaped separately. The number of seedlings in each group was recorded. All plant parts of the CBSD free seedlings were inspected closely for any disease symptoms. Roots were cut thoroughly piece-by-piece to make sure that only seedlings with no any CBSD symptoms (class 1) were selected for further evaluation. Roots of the seedlings painted red were also chopped to look for symptoms in the storage tissues (root necrosis). The number of seedlings that showed root necrosis in the two groups was also recorded.

Seedlings among the CBSD free heap that did not have any CBSD symptoms or severe CMD symptoms were tagged and given a number. Then the following data were recorded from each: Number of roots per plant, plant height, branching height, inner root skin colour, root pulp colour, number of stems. These traits will be followed up in subsequent trials to determine whether their expression at seedling stage correlated with their clonal stages.

The Percentage Number of Seedlings with Foliar Symptoms (PNSFS) was calculated by dividing the number of seedlings selected from each family by the number of harvested seedlings multiplied by one hundred. Foliar symptoms were taken as synonymous with above ground symptoms i.e. symptoms on stems and leaves. The Percentage Number of Seedlings with Root Symptoms (PNSRS) was calculated by dividing the number of

seedlings with root symptoms (necrosis) in each family by the number of seedlings with foliar symptoms (PNSFS).

Clonal Evaluation Trial (CET). Clones selected from the seedling trial were cloned and planted at three sites: Kibaha, a hot spot for both CMD and CBSD but poor soils (513 clones), Alavi estate, 10 km from Kibaha, where an entrepreneur (Mohamed Enterprises – MeTL) intends to establish a large cassava starch factory (480) and Zanzibar (170 clones). Planting was done in December 2002. Three cuttings per clone were planted. A check plot design was used where a local check was planted after every ten clones. The spacing of 1.0m x 1.0m was used. Plant height, pest and disease scores were taken at three months intervals up to harvesting. Painting their stems marked diseased plants. Red paint was used to mark CBSD affected plants, whereas black paint was used for CMD. Diseases and pests were subjectively scored on a scale of 1 – 5, where class 1 indicated no symptoms and class 5 very severe symptoms.

Open Quarantine Facility (OQF). In order to increase the number of resistant cultivars available to farmers, about 457 clones were introduced into the OQF (established at Kibaha, Tanzania in March 2003, Fig. 1) from the East African Root crops Research Network (EARRNET) breeding program at KARI Mtwapa, near Mombasa, Kenya. Mtwapa is a CBSD hot spot. Only clones, which did not show any CMD and CBSD symptoms, were introduced. The clones were also selected on the basis of their high yielding ability and high dry matter content. One stem per clone was taken. At Kibaha, each stem was cut into four cuttings and planted in the OQF. Planting was done on 4th May 2003. The spacing of 0.5m x 0.5m was used. After sprouting, the plants were closely inspected (weekly) for any disease symptoms (both CMD and CBSD). Plants showing any symptoms were recorded and then rouged and buried. After every two months, inspectors from the post-entry quarantine station based

at Arusha inspected the plants to make sure that only apparently disease free plants will be multiplied after the one-year compulsory confinement in the OQF. The OQF is located in isolation (at least 200m from the nearest cassava crop), fenced and guarded.

Crossing block. In order to generate new genotypes, which combine resistance to both CMD and CBSD, a crossing block was established at ARI Kibaha, Tanzania. The following cultivars were used: Kiroba, Amani 46106/27, NDL 90/34, Namikonga, Kigoma Red, Kitumbua (CBSD tolerant/resistant); Kibaha and TMS 4(2) 1425 (CMD resistant). Planting was done in April 2003. A randomised complete block design was used, with four replications. One row of ten plants constituted a plot. The spacing of 1.5m x 1.5m was used. A full diallel mating system will be used to generate F1 seeds for genetic studies.

Results

Out of 12,341 seedlings transplanted to the field 9,949 were well-established three months after planting (MAP). However, at harvest only 4,351 seedlings from 118 families were large and vigorous enough to be considered for further evaluation (Table 1). Hereafter, these will be referred to as the number of seedlings harvested.

The procedure of marking diseased plants with paint significantly made the harvesting and selection work much easier. Above ground CBSD symptoms may disappear due to leaf-fall and therefore, infected plants might look symptom-free at a later time of inspection.

About 88% of the harvested seedlings showed above ground CBSD symptoms, (mostly on leaves), among which 83% had root necrosis (Table 1). Only symptom-free seedlings were selected for further evaluation. A total of 513 such seedlings were selected (Table 1). Among the families which had a reasonably high number of seedlings harvested (more than 30), the following families had high PNSS (>50%): Kiroba (65%), 71762 (70%), and I88/00188 (60%).

At 9 MAP the majority of clones in the CET were apparently disease free both at Kibaha and Alavi estate (Table 2). Only twenty clones at Kibaha and 10 at Alavi estate had plants with maximum scores of class 3 for CBSD, which implies they are moderately susceptible to the disease. For CMD, 77 clones at Kibaha and 69 at Alavi estate had plants with maximum scores of class 4 – 5, indicating that they are highly susceptible to the disease (Table 2). Many clones at both sites showed high susceptibility to green mites, most probably due to the severe drought experienced this season. About 127 and 135 clones at Kibaha and Alavi estate respectively had plants, which showed high susceptibility to green mites (maximum scores of class 4 – 5).

Plant establishment in the OQF was very excellent due to watering. By the end of October 2003 (5 MAP), 169 (37%) clones out of the 457 introduced into the OQF had all their plants rouged. Out of the 288 (63%)

clones remaining, only 97 (21%) had all plants free of disease symptoms.

Discussion

Ruling out the possibility of seed-borne transmission (of which there is no evidence), the very high percentage of seedlings showing CBSD symptoms proves that at ARI Kibaha, high disease spread by the yet unknown vector occurred. Therefore, there is a high chance that, seedlings that did not show any CBSD symptoms and were therefore selected for further evaluation were not escapees. When you have a high NSH per family, and where the disease spreads easily and widely, PNSS can be a very good selection criterion for resistance to CBSD. Resistant varieties have been reported to remain symptom-free, and when symptoms did occur they were usually mild and frequently confined to the roots (Jennings, 1960). Families with a high PNSS could have a

Table 1: Summary of the data recorded during harvesting of cassava seedlings at Kibaha, 2001/02 season.

No. of seedlings harvested	No. of seedlings selected	No. of seedlings with foliar symptoms	No. of seedlings with root symptoms	Families with high PNSS	Families with low PNSS
4,351	513	3838 (88%)	3179 (83%)	Kiroba (65%) 188100188 (60%) 71762 (30%)	Kiroba (26%) 71762 (30%)

Table 2: Reaction of clones to CMD, CBSD and green mites evaluated in the CET at Kibaha and Alavi estate, 9 MAP during the 2002/03. season.

Maximum score	CMD		CBSD		Green mites	
	Kibaha	Alavi	Kibaha	Alavi	Kibaha	Alavi
Class 1	298	158	386	284	0	1
Class 2	69	45	75	34	158	192
Class 3	37	56	20	10	196	107
Class 4	48	51	0	0	88	28
Class 5	29	18	0	0	39	0
Total	481	328	481	328	481	328

high general combining ability for resistance to the disease.

The fact that the majority of clones in the CET remain free from both CMD and CBSD symptoms 9 MAP imply that they might be resistant to the diseases. The trial will be harvested in December 2003. Farmers will be invited to select clones, which they prefer. Researchers will document the selection criteria used by the farmers. The clones, which the farmers have selected, will be multiplied using rapid multiplication techniques so as to have enough planting material of each for on-farm evaluation the following season. Fast tract evaluation of the clones will be done both on station and on-farm using a decentralised, farmer participatory approach. This will ensure that the clones, which will perform well, on-farm, will be widely adopted, because they will possess traits that combine farmers' preference with agro-ecology specific adaptation. Farmers in these areas will within a short time (4–5 years instead of 8–10 years by conventional breeding scheme) therefore, have access to a wider range of improved varieties.

The fact that 79% of the clones introduced into the OQF had primary infection (cutting infection) highlights the difficulty of visual selection for clean planting material. Since the plants were regularly closely inspected for any disease symptoms at Mtwapa, it seems both of the two virus diseases remained latent in some clones and symptoms were expressed when grown at the new environment.

Conclusions

- Evidence of the spread of CBSD by the unknown vector has been obtained from this study
- Preliminary results indicates that the locally adapted CBSD tolerant cultivar “Kiroba” might be a good parent for use in breeding for CBSD resistance
- The majority of clones evaluated in the CET seem to be resistant to both CMD and CBSD because they remained free of symptoms 9 MAP

- The use of the OQF has facilitated the quick and efficient introduction of improved germplasm
- Visual selection for disease free planting material is a very unreliable method

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Sweetpotato crop improvement in sub-Saharan Africa and future challenges

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Abstract. In sub-Saharan Africa region, most sweetpotato are produced from diverse landraces that have constant turnover. The preference for high dry matter is between 28 to 35%. CIP breeding strategy for the past 15 years has been to collect, characterize, and conserve farmers' varieties; evaluate and distribute the best performers regionally. It has also emphasised population development through crosses and systematic screening with partners using participatory methods. Key stages of breeding programme incorporate breeders, ICM specialists, post-harvest technologists, social scientists, consumers and farmers. To-date several varieties have been released officially by the national programmes and of recent orange-fleshed sweetpotato (OFSP) varieties have been given emphasis in almost all the countries in ASARECA and SADC regions. Varieties such as: SPK004, Mogamba, Zapallo (for children), Salyboro, Pumpkin, SPK 013, and Kemb10 (yellow-fleshed), Zapallo, Japon Tresminiso, Tainung 64, Resisto and Kande have gained popularity. Multiplication and distribution of planting materials have continued by individual farmers and community based organizations. In Western Kenya, about 30 million cuttings of mainly

OFSP varieties have been distributed to farmers from KARI stations and local CBO's/ NGO's. In the Lake Zone of Tanzania, about 6 million of three newly released varieties (SP93/23, SP93/2, and SP93/34) together with local varieties Sinia and Simama (SPN/O); and in Uganda farmers with BUCADEF and SOCADIDO have distributed about 10 million cuttings of the newly NARO released varieties (NASPOTs 1-5) to farmers. Improved varieties distributed in East African region, have covered over 360 hectares of fields. In Mozambique an estimated 154 ha have been planted with improved varieties. Over 347,000 households in Mozambique have received at least 200 vines of OFSP sweet potato and projections are that over one million households will have received planting material by 2004.

Introduction

Sweetpotato (*Ipomoea batatas* Lam) is among the world's most important, versatile, and under exploited food crops (Woolfe, 1992). With more than 133 million tons in annual production, sweetpotato currently ranks as the fifth most important food crop on a fresh-weight basis in developing countries after

rice, wheat, maize, and cassava. Sweetpotato is cultivated in over 100 developing countries and ranks among the five most important food crops in over 50. Only in the last decade has the crop been the focus of an intense, coordinated, global effort to realize its full potential as a source of food, feed, processed products, and income for millions of small farmers and low-income consumers in Africa, Asia, and Latin America.

Three facts have generated growing interest in sweetpotato. First, sweetpotato is typically a small farmer crop and often grown on marginal soils with limited outputs. Furthermore, although the crop is grown widely in Asia (31 countries), Africa (39), and Latin America (31), production tends to be concentrated in those countries with lower per capita incomes. Hence, increasing sweetpotato production and utilization is often considered as a means to improve incomes and food security among the poorer segments of the rural population.

Second, average yields in several countries are well below the average (15 t/ha) for developing countries as a whole, and these in turn are well below the current yield potential. Hence, rapid improvements in productivity are considered readily feasible with relatively less investment in research and extension than other crops, such as rice, where this is not the case.

Third, the last decade has witnessed a return to a positive growth rate for sweetpotato production in China—a remarkable reversal of previous trends in a country where some 85% of the world's output is harvested. Similar upward trends have emerged in a number of other developing countries. Some of these trends are evident from FAO statistics; others are not.

In sub-Saharan Africa (SSA) sweetpotato is grown on around 2.1 million hectares, with an estimated production of 9.9 million tons. It is one of the main staples in the food systems of Uganda, Rwanda, Burundi and Eastern Congo, with per capita production of around 100 kg per year. Sweetpotato is a secondary crop in the grain-based systems

elsewhere in the region, becoming important only at certain times of the year or when other crops fail (Scott *et al.*, 2000; Kapinga *et al.*, 2003). Sweetpotato is an important staple crop in many regions of sub-Saharan Africa. It is grown mainly for the storage roots, which are usually eaten fresh, but the leaves may also be used for forage for livestock, or eaten as a vegetable. Apart from a few key improved varieties, most cultivars presently grown are indigenous. Many constraints to the crop are prevalent, including weevils (*Cylas* spp), viruses and lack of cultivars with characteristics such as high yield, early maturity, drought resistance, good keeping qualities and high dry matter content.

Sweetpotato plays a big role as a food security crop that is always managed for reliable supply, not necessarily for maximum yields. It is easily propagated, grows reasonably well with no inputs on degraded soils over a wide range of rainfall patterns. Of recent, sweetpotato has shown an increasing demand in urban areas as a cheaper alternative to bread. Certain production areas have specialized to supply these markets e.g. Uganda: Soroti/Kumi; Kenya: Oyugis, Bungoma and Kibirigwe; Tanzania: Coast and Gairo/Morogoro; Malawi: Central zone around Lilongwe and Zambia in the Northwestern province.

In the southern countries of SADC, including South Africa, Namibia, Botswana, Zimbabwe, Swaziland and Lesotho, low yields are obtained from sweetpotato mainly because of planting old, local land races and virus-infection due to recurrent use of material for years (Thompson *et al* 1998). Another factor is unavailability of material, which is a large constraint in Namibia (Rusch, 1998).

Most sweetpotatoes are produced from diverse landraces. There are however constant turnovers since farmers introduce and reject varieties quickly. Majority are white, cream, or yellow fleshed-types and few are orange. The preference is for high dry matter - between 28 to 35%. Similarly in SADC region due to frequent drought, farmers prefer varieties that are able to produce vigorous

vines to survive dry season for the timely supply of planting materials at the on-set of rains.

CIP's sweetpotato crop improvement global strategy. As one of its mandate crops, CIP has an overall objective of conserving and using the genetic diversity for improving the sweetpotato production and utilization through the development of new varieties with enhanced post-harvesting characteristics and adaptability in developing countries. CIP's strategy begins by identifying, in close association with its clients, needs for research and technology. If these are addressed elsewhere, the Centre makes the appropriate information available through its cooperative linkages. If not, comparative advantage and priority of needs are analyzed to determine CIP's approach, involving one or more of the following operational models: encouraging the pursuit of the necessary research collaboration among countries; conducting appropriate research in cooperation with national agricultural research systems (NARS) colleagues; and initiating specialized research in the Centre's areas of comparative advantage. The effective transfer of research results, technology, and capabilities to partner countries is accomplished through training, information dissemination, and collaborative research designed to assist NARS in reaching

and maintaining their fullest potential. In mid 1990's the main breeding goals by region were as elaborated in Table 1. Of late these have expanded to incorporate the nutritional traits with the emphasis in promoting high beta-carotene sweetpotato varieties especially in SSA.

Since 1985, CIP has carried out 90 collecting expeditions with active participation of NARS of 16 countries in Latin America and the Caribbean. Other germplasm was received from AVRDC (Asian Vegetable Research Development Centre) and IITA (International Institute for Tropical Agriculture (IITA). African Root Crops research institutes have also contributed a good number of African landraces that have been used in the breeding program as parents for producing high dry matter content genotypes. The gene bank at CIP now maintains a total of 5,526 cultivated accessions, comprising 4,168 accessions of native and advanced cultivars from 57 countries (22 countries in the Americas, 26 in Asia, and 9 in Africa), and 1,358 breeding lines.

Because of the asexual propagation of sweetpotato cultivars, numerous duplicate accessions of the same cultivars have been found in the cultivated collection maintained at CIP. There is an ongoing effort to identify these duplicate accessions. Those that are morphologically identical and produce the

Table 1: Main breeding goals by region after assessment of constraints and opportunities in sweetpotato.

Factor	CIP Region			
	Latin America	S.W. Asia	E.S.E Asia and Pacific	sub-Saharan Africa
Weevil resistance/tolerance		X	X	X
Virus resistance				X
Drought tolerance	X	X	X	X
High dry matter (starch) content	X		X	X
High foliage yield	X	X		X
Non-sweet storage roots				W.Africa
Good storability	X	X		X
High beta carotene content			X	X

Source: CIP, 1995.

same electrophoretic banding patterns or DNA fingerprints are considered duplicates (Kriegner *et al.*, 2000).

The sweetpotato collection maintained at CIP has been subject to a systematic evaluation to identify sources of desirable genes that could be used in breeding programs. So far, more than 13,000 evaluations have been made and many accessions in the collection have been identified as potential sources of genes for resistance to pests and diseases, good agronomic characters, long storability, high productivity, and high nutritive value.

The genetic resources maintained at CIP are freely available for distribution in two forms: first, as clonal materials, either as *in-vitro* plantlets or as storage roots produced under quarantine conditions from pathogen-tested stocks; second, as true-seed lots. A pathogen-tested list of sweetpotato cultivars for international distribution is produced annually by CIP and it contains the most relevant data for use by researchers. CIP's policy emphasizes free access to both genetic resources and data related to each accession in the collections.

Sweetpotato crop improvement regional approach for SSA. Sweetpotato is one of the most important crops in densely populated eastern Africa. This crop is also becoming increasingly important in southern Africa. The crop is vital to destitute small-scale farmers with limited land, labor and capital. Sweetpotato performs well in poor soils lacking sufficient nutrients and water; traditional cereal crops often fail in these same environments. In eastern and southern Africa, women and girls, usually on small plots of land reserved for producing the family's food supply, grow sweetpotato predominantly. One of sweetpotatoes greatest assets as a food staple for Africa is its ability to be harvested in small amounts, as it is needed for home consumption or income generation.

CIP's sweetpotato improvement program aims at improving sweetpotato production and utilization through the development of new

varieties with enhanced post-harvesting characteristics and adaptability to low-input, subsistence farming systems. Also the program is aimed at alleviating vitamin A deficiency by extending the use of high beta-carotene sweetpotato varieties to those currently outside reach of conventional nutrition programs, with the geographical focus in the countries of eastern and southern Africa.

In recent years, breeding efforts have been intensified in eastern, central and southern Africa. This has been largely conducted under the auspices of support to key countries from CIP and the coordinating networks such as the Programme Regional de la Pomme de terre et de la Patata douce en Afrique Centrale et de l'Est. (PRAPACE), a Regional Potato and Sweetpotato Improvement Program in Eastern and the Central Africa and Southern Africa Root Crops Research Network (SARRNET). One of the key objectives of these networks is to increase the efficiency of breeding and research into the target crops by dividing responsibilities among the participating countries.

The diverse sweetpotato germplasm held at CIP are being recombined to generate superior parental clones and seeds families using conventional and biotech tools. A well established, decentralized breeding framework is using this enhanced germplasm to produce new varieties with good adaptability to cope with abiotic and biotic stresses in targeted environments. High yielding varieties with improved post-harvesting qualities, such as starch and beta-carotene content, will significantly contribute to better nutrition status and higher profits for the rural poor in the sweetpotato based agricultural system.

The sweetpotato varieties grown in Eastern and Southern Africa are mostly white fleshed, which contains only a negligible amount of beta-carotene. OFSP varieties represent the least expensive, year-round source of dietary vitamin A available to poor families in this region. As small an amount as 40 grams of OFSP sweetpotato can meet the daily requirements of preschool age children.

Replacing white-fleshed varieties now grown widely by farmers with OFSP materials can substantially increase the pro-vitamin A intake of all individuals; the vast majority of whom do not consume enough of this micronutrient to satisfy 50% of their daily requirements (Low *et al.*, 2003). The burden of Vitamin A deficiency falls largely on pre-school age children and pregnant and lactating women. These groups at risk comprise about one-third of the population. The pilot prevention study jointly conducted by CIP and its collaborating institutions in Kenya confirmed that African mothers are motivated to accept the new varieties, thus dispelling the notion that African tastes preclude the use of OFSP varieties.

Recent estimates based on geo-referenced data show the magnitude of the potential impact of replacing the currently used white-fleshed varieties of sweetpotatoes with OFSP sweetpotato varieties in six countries of eastern Africa to relieve Vitamin A Deficiency (VAD). Preliminary results indicate that each increase of one kg in per capita production of

OFSP results in a one-percent rise in the attainment of requirements up to about 25 kgs per capita (Low *et al.*, 2003). Under this scenario, assuming the harvesting season can be extended throughout the year, full adoptions of OFSP in Rwanda, Burundi, and Uganda could lead to an average increase of 50% in the attainment of Vitamin A requirements. Even in countries such as Ethiopia, about 30% of the population enjoy partial benefits in enhanced pro-vitamin A intake from switching white flesh to orange-fleshed varieties of sweetpotato.

In the last five years, our African collaborating institutions from materials selected from CIP mediated germplasm or CIP developed breeding lines have released 45 sweetpotato varieties. International distribution of seed populations for selection by breeding programmes has been carried out by CIP for 2000-2003 cropping seasons (Table 2). Principal sources have included the CIP breeding programmes in Peru and Indonesia, the Chinese programmes, Mississippi State University (USA), and the USDA Vegetable

Table 2: Sweetpotato germplasm distributed by CIP to East, Central and Southern Africa countries from 1993 to 2003.

Country of destination	Source of germplasm			No. of seed families received
	South America (CIP, Lima)	North America	Other countries	
Angola	16	4	21	-
Burundi	2	-	4	-
Botswana	17	4	13	-
DR. Congo	20	17	36	22
Eritrea	-	-	18	-
Ethiopia	21	-	26	-
Madagascar	7	-	4	-
Malawi	8	-	20	45
Mozambique	32	-	28	11
Kenya	73	41	171	265
Rwanda	45	21	41	92
Sudan	22	4	29	-
Tanzania	28	7	60	149
Uganda	83	34	116	117
Zambia	23	3	48	234

Source: CIP Annual Reports (1999- 2003).

Research Laboratory (S. Caroline, USA). In the past the ISAR Programme in Rwanda served as a source of seed for distribution both within and outside of Africa. More recently, Namulonge, Uganda and Roodeplat, South Africa have become principal sources of seed in the east and southern African countries. The seeds are generated from the crossing blocks as well as open pollinated fields. The parents used are both from the region as well as introductions from other countries through CIP. Kenya having an advantage of hosting CIP serves as the principal regional location for the regional redistribution of clonal germplasm by CIP from the Kenya Plant Quarantine Station at Muguga.

The introductions by country have been supported by evaluations and rigorous multiplication schemes. This has enabled new germplasm to be evaluated in the national breeding trials. Results from different countries have shown that many of the clones initially selected from IITA have poor performance with respect to dry matter content, indicating a need for using regionally adapted parental clones with acceptable qualities e.g. SPN/O, Mugande, etc. In fact Mwanga *et al.*, 2001, have shown that most varieties selected which have reached the advanced breeding stage, have the regionally important sweetpotato variety, SPN/O as their female progenitor.

Breeding priorities in SSA. To increase production and efficiency, CIP has been working with key breeding institutions in SSA. African breeders have taken the population improvement approach. The population mean has steadily increased due to the efficient recombination of new genes and traits from the local germplasm and the introduced ones. The new generation of parental clones will be developed in foreseeable future.

The breeding programs in SSA have always taken a holistic approach with different components. These include: collection, characterization, and conservation of farmers'

varieties, regional distribution of best performers and the introduction of best cultivars from other parts of the world. Seeds are mainly generated by the national crossing programs in Uganda (for East and Central African countries), Zambia and South Africa for the Southern African countries. In all countries systematic screening with partners using participatory methods, based on study of genotype by environmental effects continues.

The primary breeding objectives aim at selecting varieties that are acceptable with respect to utilization characteristics. These include: acceptable taste, high dry matter content, suitability for improved farm-level processing, extended shelf life of roots and tolerance to market conditions, attractive appearance and properties of products particularly flour and ability to produce vines for animal feed. Of recent, breeding for high beta-carotene content a precursor of Vitamin A has received high priority. Secondary traits include: earliness vs. in-ground storability, drought tolerance, high root yield, good establishment, and good resistance to SPVD and sweet potato weevils. All these in addition to socio-economic factors pose as constraints limiting the increased production of sweetpotato in the region (Table 3).

Achievements

Over nineteen million vine cuttings of popular varieties were distributed to farmers during the year 2003. This is estimated to have covered about 600 hectares of farmers' fields. OFSP varieties are currently estimated to occupy 1-2% in the Lake zone of Tanzania, 15-20% in Central Uganda, 10-15% in Mozambique, and 10-15% in W. Kenya. (CIP, 2002).

Improved varieties have continued to be introduced from CIP, Lima Peru and shared with other countries in the region as indicated earlier on. There have been also deliberate efforts to introduce high dry matter varieties with high beta-carotene content for inclusion in the breeding programs. Of the 40 varieties

Table 3: Major constraints to the sweetpotato crop identified in sub-Saharan Africa.

Type	Constraint
Biotic	Viruses Weevils (mainly <i>Cylas</i> species)
Abiotic	Declining soil fertility and natural resource base
Available varieties and planting material	Lack of varieties that are high yielding, early maturing, drought resistant, have high dry matter and have high beta carotene contents Lack of good quality planting material of improved varieties
Post-harvest	Lack of storage and processing technology Lack of varieties that are less perishable Opportunity for utilization and marketing not well developed
Socio-economic and policy	Lack of policy for the production and supply of seed or planting material Lack of market studies and weak distribution systems Poor linkage between research, extension and private sector Lack of credit systems and inability of farmers to purchase inputs

Source: Kapinga and Carey, 2003a.

already developed at CIP, Lima, twenty clones were introduced to Muguga, Kenya in early 2003 (Table 4). These have been multiplied and now they are ready for dissemination to other countries. All varieties developed or introduced are normally tested in different agro-ecologies for adaptability and acceptability in individual countries. In most cases, yield performances of most of varieties are higher or equal to that obtained in landraces (Table 5). Most preferred varieties have been identified and released/ pre-released in different countries. Among them are: Zapallo, Tainung 64, W – 151, Jewel, Mafutha, Jonathan, Ejumula (Table 6). In South Africa, varieties W-19 and Excel have been selected for high dry matter, high beta-carotene content while variety 1656-97 has been selected for processing into products (Laurie *et al.*, 2003). Most of the varieties have high dry matter content, a characteristic that contributes to their acceptability.

Some fourteen different viruses or virus-like agents have been identified as affecting sweetpotato. Virus diseases can cause substantial damage in both temperate and tropical regions. It is particularly serious in

East Africa (INCO-DEV., 2002). The development of virus-resistant or tolerant cultivars has been the most effective means of reducing sweetpotato losses from virus infection. A few African cultivars have been identified as having high-level field resistance to sweetpotato virus complex. These cultivars are now used intensively as resistance sources in breeding programs in CIP-Lima, Africa, and China.

Sweetpotato variety adoption study completed in Western Kenya and results show that at least 70% of sweetpotato growers have adopted one or two new varieties. Preferred varieties are: Mugande, SPK 004 and Kemb 10. Key impacts noted are: improved self-sufficiency in food supply at least 20% and improved incomes mainly by women in Kakamega district up to 30%. Also farmers in Mwanza district, Lake Zone of Tanzania and Uganda indicated significant increase of food supply and rural incomes for household cores. In Kenya varieties with high dry matter and other desirable characters were evaluated and advanced to different breeding advanced stages per attached details. Varieties: Kanziga1, and 2; Cemsu, Mugamba, Bikira

Table 4: High dry matter content and high beta-carotene clones distributed to selected countries in SSA, 2003.

CIP number	Pedigree	Origin	DM (%)	Skin colour	Flesh colour	Reaction to root knot nematode
199004.2	CC89.147. 4 x OP	CIP breeding lines	34	Red	Light orange	R
199004.3	CC89.147. 4 x OP	CIP breeding lines	33	Red	Intermediate orange	MR
199005.11	CHGU 1.002 x OP	CIP breeding lines	26	Pink	Intermediate orange	R
199015.13	LM92.032 x OP	CIP breeding lines	31	Cream	Pale Yellow	R
199015.14	LM92.032 x OP	CIP breeding lines	25	Yellow	Interm. Orange	R
199024.1	SR91.109 x OP	CIP breeding lines	26	Cream	Light orange	MR
199024.2	SR91.109 x OP	CIP breeding lines	26	Red	Light orange	R
199025.2	SR92.095. 3 x OP	CIP breeding lines	25	Orange	Light orange	R
199026.1	SR92.095. 8 x OP	CIP breeding lines	26	Red	Light orange	R
199027.1	SR92.095. 10 x OP	CIP breeding lines	31	Red	Pale Yellow	MR
199027.3	SR92.095. 10 x OP	CIP breeding lines	26	Red	Light orange	R
199034.1	SR95.628 x OP	CIP breeding lines	34	Red	Dark Yellow	R
199034.1	SR95.628 x OP	CIP breeding lines	34	Red	Dark Yellow	R
199035.1	SR95.636 x OP	CIP breeding lines	25	Orange	Light orange	MR
199035.5	SR95.636 x OP	CIP breeding lines	25	Purple	Orange-purple	R
199035.7	SR95.636 x OP	CIP breeding lines	30	Cream	Light orange	R
199035.8	SR95.636 x OP	CIP breeding lines	37	Red	Pale Yellow	MR
195037.2	SR90.411 x OP	CIP breeding lines	28	Red	Light orange	MR
199057.4	LM94.422 x OP	CIP breeding lines	34	Purple	Light orange	R
199062.1	SPV 78.001. 3 x OP	CIP breeding lines	30	Orange	Interm. Orange	R
199073.1	SR95.478 x OP	CIP breeding lines	31	Brown	Pale Yellow	R
440203	Hong Mi	Korean cultivar	28		Light orange	unknown
440262	Chin Mi	Korean cultivar	28		Light orange	unknown
440443	Nashu 88	Chinese cultivar	28	Yellow	Light orange	unknown
440445	Chuan 29-4	Chinese cultivar	27	Yellow	Light orange	unknown

MR- Moderate resistant; R- Resistant.

Table 5: Yield performance of OFSP clones across 4 environments in Uganda, 2002/2003.

CIP code	Clone	Storage root yield (t/ha)				Means
		NAARI	Kacwekano	Ngetta	SAARI	
440189	Tainung No. 64	45.7	42.5	33.3	32	38.4
420009	Japon Tres.	19.5	21.4	11.4	14.1	16.6
440016	Excel	36.3	21.5	22.0	10.4	22.5
440060	TIB 4	39.5	9.0	8.4	13.4	17.6
420027	Zapallo	29.9	47.5	20.9	22.4	30.2
187017.1	Salyboro	41.7	41.9	15.9	32.4	33.0
440140	Kandee	25.0	18.9	11.5	24.4	20.0
440005	W-151	21.0	16.8	18.5	18.5	18.7
440215	Tainung No. 65	19.0	33.5	10.1	47.0	27.4
420005	Nemanete	26.4	27.8	15.0	18.2	21.8
440112	Centenial	26.2	14.5	16.6	9.7	16.8
556638	Jewel	5.7	32.5	10.6	3.5	13.1
440288	VSP 4	15.0	23.7	11.1	28.5	19.6
420014	Jonathan	19.0	17.6	14.0	19.7	17.6
440031	Jewel	23.6	23.5	28.2	12.6	22.0
440141	Julian	5.8	9.6	12.9	6.7	8.7
440293	BP-SP-2	46.6	44.5	52.3	32.3	43.9
440018	W-223	40.5	29.0	29.9	30.0	32.4
440090	CN 317	46.6	29.0	16.7	14.4	26.7
Land race	Sudan	20.3	21.5	30.4	15.5	21.9
Land race	Ejumula	42.8	29.4	49.6	24.0	36.4
Land race	Kala	47.0	22.5	43.8	25.4	34.7
-	SPK 004	35.5	24.9	47.0	16.7	31.0
Land race	Mahuri	40.5	32.0	40.2	24.3	34.2
-	TZ (check 1)	23.5	26.7	44.0	9.5	25.9
Land race	Sowola-6	13.4	22.3	22.6	3.3	15.4
	Local check 2	45.8	NA	24.7	NA	NA
Mean		29.7	26.3	24.5	19.6	24.9
LSD _{0.05}		5.3	5.5	4.4	6	2.7
CV (%)		12.8	14.9	12.7	21.9	15.3

Source: McKnight Uganda report, 2003.

Maria, 320/06 316/02 and Polista have selected by farmers for on-farm testing. Polista was recommended specifically for targeting the drier environments of Western Kenya. Five varieties have been selected by farmers for foliage production in zero grazing farming at Kabete, Kenya. These include TZ-L- 13, Bit-L-30, 316-H-20, WK-L-8 and Toro-L-5.

Multidisciplinary team approach in the national breeding programs is being employed in the evaluation of sweetpotato varieties. Key stages of breeding program incorporate

breeders, ICM specialists, post-harvest technologists, social scientists, consumers and farmers. Farmers in Kenya, Tanzania and Uganda have evaluated OFSP varieties. Preferred varieties include: SPK004, Mogamba, Zapallo (for children), Sayboro, Pumpkin, SPK 013, and Kemb10 (yellow-fleshed). Increased markets of orange- fleshed varieties (both roots and vines). In the Lake Zone of Tanzania, 49 clones (hybrids from crosses of South African orange- fleshed germplasm) have preliminarily been identified

Table 6: Popular sweetpotato varieties (released and near release) currently disseminated in selected SSA countries.

Country	Disseminated varieties		Collaborating partners**
	Non OFSP	OFSP	
Uganda	NewKawogo, Naspot 1, TZ, Kyabandula, Magabale	SPK 004, Ejumula, Kala	AFRICARE, BUCADEF, JAF, SOCADIDO, Parliamentarians, NAADS, Farmer groups
Kenya	Marooko, Kalumb, Nyerere, Jayalo, Nyathodiweo, Ex-Diani, Muibai	Kemb 10, SPK004, SPK013, KSP20, Mwavuli, 566682/03, Salyboro, Kazinga 2-1, Mogamba	Resource Project Kenya (RPK), Christian Partners Development Agency (CPDA), Africa Now, Rural Energy Food Security Organization (REFSO), Appropriate Rural Development Agricultural Programme (ARDAP), Catholic Relief Services (CRS), Akukuranut Development Trust (ADT)
Mozambique	Chingowwa, Nemanete,	Japon Tres., Zapallo, Mafuta, Zondeni, Resisto	CARE, Action Aid, CRS., SARRNET, Save Children, World Vision, INIA, World Relief, Farmer groups
Tanzania	Simama, Juhudi, Sinia, Mavuno, Vumilia	Zapallo, Japon Tres.	CCT, TAHEA, Plan International, WI, KAEMP, CARE-Magu, AIC, EGAJ, World Vision -Magubike, MAF-S-Crop promotion, Farmer groups
S. Africa	Mafutha, Bosbok, Ndou, Monate, Mokone, Lethabula, Amasi, Phala, Mamphenyane	Resisto, Mafuta, Japon Tres., Excel, Jewel, W-119	-
Ghana	Sauti, Okumkom, Santum Pona, Faara,	-	UNICEF, Farmer groups
Rwanda	Mugande, Wadada, K51/3261, TIS2498	Kwezikumwe, 97-046, 97-004, 4-143	UNICEF, Farmer groups, CRS
Ethiopia	Koka 6, Koka12, 192009 – IX, 192026 – II, Belella, Awassa 83, Dubo, Falaha, Damota	-	-
Malawi	Mugamba, Camsa 74-288, Salera, yoyera, Babache, Kakoma, Kenya	Kanchiputu, Tainoni, Zodeni	SARRNET, Extension Agents

**-. List not exclusive.

with dry matter contents ranging between 29% and 42%. Majorities have good resistance to sweetpotato weevils and viruses. Rural incomes from sales of OFSP planting materials and storage roots by farmers in Uganda have increased significantly. Some farmers have recorded success stories in their improved life standards through the sale of both roots and vines (www.cipotato.org/vitaa).

Multiplication and distribution of planting materials have continued by individual farmers and community based organizations. In Western Kenya, about 18 million cuttings of mainly OFSP varieties have been distributed to farmers from KARI stations and local CBO's/ NGO's. In the Lake Zone of Tanzania, about 2.5 million of newly three released varieties (SP93/23, SP93/2, and SP93/34) together with local varieties Sinia and Simama (SPN/O) were distributed by farmers' groups and local NGO's. In Uganda farmers with BUCADEF and SOCADIDO have distributed about five million cuttings of the newly NARO released varieties (NASPOT's 1-5) to farmers through sale/ free. 15-20 promising OFSP clones have been identified and selected by farmers through participatory evaluation in SSA. Improved sweetpotato varieties currently grown by farmers in major growing areas of Kenya, Tanzania and Uganda form at least 30% of the total planted area. Efficient and sustainable planting material dissemination mechanism is in place. There is an increased use of participatory research approaches by NARS in varietal evaluations and selection for promotion in sweetpotato growing areas. Varieties suitable for livestock feed have been identified. These are to be promoted in the livestock production sector. Experiences between NARS Root Crops Programs are exchanged through Networks (SARRNET and PRAPACE). These have facilitated resource mobilization and sharing of responsibilities based on the existing capacities. The number of OFSP varieties currently evaluated in the region has increased tremendously. There is increased acceptance and consumption of OFSP

varieties by consumers mainly children and caregivers.

Summary

To-date several varieties have been released officially by the national programs and of recent orange-fleshed sweetpotato (OFSP) varieties have been given emphasis in almost all the countries in ASARECA and SADC regions. Varieties such as: SPK004, Mogamba, Zapallo (for children), Salyboro, Pumpkin, SPK 013, and Kemb10 (yellow-fleshed), Zapallo, Japon Tresmesino, Salyboro, Tainung 64, Resisto and Kandeel have gained popularity. Multiplication and distribution of planting materials have continued by individual farmers and community based organizations. In Western Kenya, about 30 million cuttings of mainly OFSP varieties have been distributed to farmers from KARI stations and local CBO's/ NGO's. In the Lake Zone of Tanzania, about 6 million of newly three released varieties (SP93/23, SP93/2, and SP93/34) together with local varieties Sinia and Simama (SPN/O); and in Uganda farmers with BUCADEF and SOCADIDO have distributed about 10 million cuttings of the newly NARO released varieties (NASPOT's 1-5) to farmers through sale/ free. Improved varieties distributed in East African region, have covered over 360 hectares of fields. In Mozambique an estimated 154 ha have been planted with improved varieties. Over 347,000 households in Mozambique have received at least 200 vines of OFSP sweet potato and projections are that over one million households will have received material by 2004. Crop diversification policies due to drought in Malawi and Zambia and social disruptions in Zimbabwe.

Future challenges. Developing and selecting sweetpotato varieties for animal feeds. Recent research has documented the widespread use of sweetpotato by small farmers in their efforts to sustain local livestock production systems. In fact, virtually wherever sweetpotato is

cultivated, some part of the plant, in some form, is used in some type of animal production. These trends need to be facilitated by the introduction and take-up of higher-yielding sweetpotato varieties with appropriate post-harvest traits integrated with improvements in small-to-medium scale food processing and pig production. In SSA, improvements in sweetpotato germplasm for feed, for example, can reduce dependence on imported cereals as more roots and vines can be substituted for maize in the pork industry. This should also make farmers and village enterprises less reliant on imported concentrates for raising pigs.

1. Improvement of sweetpotato varieties for starch industry and potentially for bio-based fuel source. In China, the processed products made from sweetpotato including starch, ethanol, starch based chemical products, noodles, candy, desserts, and flour have long been made by farm households to extend the availability, diversify the use, and increase the value-added for the crop (Li *et al.*, 2001). Sweetpotato is an abundant and renewable resource, and the search for energy alternatives makes it a natural choice as a fuel source. To reach this goal, CIP and the breeding programs in SSA need to use both conventional and biotech approaches to enhance the starch yield of sweetpotato.
2. Enrich genetic diversity in SSA breeding programmes and enhance sweetpotato dry matter yield. So far, most of the African cultivars have very low yields and moderate DM content of <30%. In recent years, post-harvest processing of sweetpotato has become an important way for farmers to increase their incomes. Existing cultivars do not meet these demands. Disease-resistant cultivars with high starch content and high DM yield are urgently needed. Given the lack of progress, there appears to be a need for an infusion of new sources of genetic diversity. Biotech

approaches to improve productivity, weevil resistance and dry matter content in sweetpotato should also be given emphasis in the long run.

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Virus diseases of root crops in Africa: An overview

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Abstract. Virus diseases are some of the most economically important constraints to the production of the root crops: cassava, sweetpotato and yams in sub-Saharan Africa. Cassava is affected primarily by two virus diseases: cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). CMD, caused by a group of cassava mosaic begomoviruses, is present in all cassava-growing areas of Africa, on average affects half of all plants, and is responsible for continent-wide losses in excess of US\$ 1 billion annually, arguably making it globally the most important plant virus disease. This impact is currently being exacerbated by a pandemic of an unusually severe form of the disease. CBSD, caused by cassava brown streak virus, an ipomovirus, is most important in coastal East Africa where it leads to lost production through producing a brown necrotic root rot. Recent reports suggest it may also now be damaging cassava in parts of central Africa. Sweetpotato in Africa is attacked by a large number of viruses, although only two are of major economic importance. Sweetpotato chlorotic stunt virus, a crinivirus, and Sweetpotato feathery mottle virus, a potyvirus, commonly occur in sweetpotato plants in mixed infection, giving rise to sweetpotato virus disease (SPVD). In farmers' fields, incidences of greater than 30% are frequent, particularly in the Lake Victoria zone of East Africa, where the disease is most damaging. However, perhaps SPVD's most pernicious effect is to prevent farmers growing superior high-yielding genotypes, particularly ones from outside Africa, as these are

generally extremely susceptible to it. Yam is similarly affected by a broad range of viruses, but the most widespread and economically damaging is Yam mosaic virus (YMV), a potyvirus, which occurs throughout the major yam-producing zone of West Africa, commonly at incidences in excess of 50%. Other potyviruses, a badnavirus (*Dioscorea alata* virus), and other viruses (including a cucumovirus and a comovirus) cause leaf symptoms that result in chronic and sometimes severe tuber losses. Whilst the virus threat to African root crops appears to be as great as ever, substantial progress has been made in developing control methods, most notably through the development of virus resistant germplasm and by identifying appropriate cultural controls. The challenge for the future will be to combine these approaches into integrated management strategies and ensure that they reach the producers for whose livelihoods these root crops are so essential.

Introduction

Root Crops in Africa. Tropical root crops are a vital component of the food systems of sub-Saharan Africa, most importantly within the humid and semi-humid zones lying between the Tropics of Capricorn and Cancer. A diversity of root crops is cultivated, but the three of greatest importance in terms of their distribution and overall production are cassava (*Manihot esculenta* Crantz), sweetpotato (*Ipomoea batatas* L.) and yams (*Dioscorea* spp.). Cassava is grown virtually

throughout the tropical belt of sub-Saharan Africa, running from Senegal in the north-west to Madagascar in the south-east. Total fresh weight production is greater than 100 million tonnes (FAO, 2003), and whilst cassava is a semi-perennial, typically maturing in 12 months, much of its success lies in its tolerance of drought and poor soils. Sweetpotato matures in four to six months, is also relatively tolerant of drought, but is primarily cultivated in the Great Lakes region of East and Central Africa. Continental production is slightly over 11 million tonnes (FAO, 2003). A number of yam species are commonly cultivated. These include: white yam, *Dioscorea rotundata* Poir., water yam *Dioscorea alata* L. and yellow yam *Dioscorea cayenensis* (Lam.). The species have different geographical distributions, but the main production zone is in the central-southern part of West Africa running from Nigeria to Ivory Coast. White yam is preferred in Nigeria, Benin and Togo but there is wider cultivation of yellow yam further west in Ghana and Ivory Coast. Total production of yams in Africa is > 38 million tonnes (FAO, 2003). Yams require higher potential growing conditions than either cassava or sweetpotato and have a complex set of cultivation and harvesting systems. Significantly, they also have important functions within the social systems of the major producer countries in West Africa, particularly Nigeria. As a result, they have a very high local commercial value. All three of the crops are nevertheless primarily grown for subsistence, and there is limited development of processing and utilization options that might provide enhanced commercial opportunities.

Biotic Constraints to Root Crop Production.

Yams are considered to be indigenous to Africa, whilst both cassava and sweetpotato have been introduced from Latin America. Partly as a consequence of this external origin, cassava had been relatively unaffected by major pests and diseases for much of its history in Africa following its introduction in the 16th century. Three of the most important

pests/disease problems have arisen from recent (1970s) accidental introductions. These include the cassava mealybug (*Phenacoccus manihoti* Matt.-Ferr.), the cassava green mite [*Mononychellus tanajoa* (Bondar)] and cassava bacterial blight (*Xanthomonas axonopodis* pv. *manihotis*). The first two became continent-wide problems causing major losses in virtually all cassava-growing areas, but both are now under effective management following the implementation of classical biological control programmes (Herren and Neuenschwander, 1991). The two other major biotic constraints to cassava production are the virus diseases, cassava mosaic virus disease (CMD) and cassava brown streak virus disease (CBSD). Sweetpotato is attacked by a diverse range of pests and diseases, the most widely occurring and economically important of which are: sweetpotato weevils (*Cylas* spp.), sweetpotato butterfly (*Acraea acerata* Hew.), *Alternaria* leaf blight and sweetpotato virus disease (SPVD). Yams similarly have a wide range of pest and disease constraints. Nematodes, including *Scutellonema bradys* (Steiner and LeHew) and *Meloidogyne* spp. cause major losses and anthracnose disease, caused by the fungal pathogen *Colletotrichum gloeosporioides* Penz., is also a key production constraint. Yams are affected by a number of virus species, the most important of which is *Yam mosaic virus* (YMV), which occurs throughout the major yam-producing zone of West Africa.

Cassava, sweetpotato and yams are all propagated through vegetative material, although there is some limited use of seed by farmers. The use of vegetative propagation means that viruses that infect parental material are carried with vegetative propagules into the new crop. This is a key facet of the biology of the interaction between viruses and their root crop hosts. It helps to explain why virus infection can be found in virtually all fields of the three crops yet also why, under normal circumstances, symptoms are chronic and mild rather than acute and severe, since viruses that have limited effects on their hosts

are more likely to be propagated than those that have more drastic and noticeable effects. Vegetative propagation, whilst perpetuating systemic virus infections, does not facilitate spread. Adaptation to transmission by insect vectors, however, allows severe virus variants or virus combinations to be carried rapidly and over large distances in epidemics.

Virus Diseases of Cassava

Introduction. Although eight virus species have been reported from cassava in Africa (Calvert and Thresh, 2002), only two groups occur widely and cause economic damage. These are the cassava mosaic geminiviruses (CMGs) (*Geminiviridae: Begomovirus*) that cause CMD and cassava brown streak virus (CBSV) (*Potyviridae: Ipomovirus*) that causes CBSD.

CMD was first described more than a century ago (Warburg, 1894) and CBSD has also been recognised for many years, having first been reported from what is now Tanzania in the 1930s by Storey (1936). Symptoms comprise a chlorotic yellow or yellow-green mosaic on the leaves, reduction in size and deformation of leaves, and general plant stunting, all leading to reductions in tuberous root production. CMD is arguably Africa's most damaging pathogen. It occurs wherever cassava is grown in Africa (Fauquet and Fargette, 1990), affects approximately half of all plants (Legg and Thresh, 2003) and causes losses estimated at in excess of US\$ 1,200 annually (Thresh *et al.*, 1997). During the 1990s, a pandemic of unusually severe CMD, first reported in Uganda (Gibson *et al.*, 1996; Otim-Nape *et al.*, 1997) was subsequently recorded as spreading widely through East and Central Africa (Legg, 1999) devastating cassava production and commonly leading to the abandonment of the crop. Most recent spread has been documented from north-eastern Burundi and eastern Gabon (Legg, unpublished data). As a result of this further spread of the pandemic, the economic importance of CMD continues to increase.

CBSD has been reported from Kenya, Tanzania, Mozambique, Zambia, Malawi and Uganda, but the incidence and effects of the disease are greatest in lowland coastal areas of Kenya, Tanzania and Mozambique where incidences commonly exceed 50% (Thresh and Mbwana, 1998; Hillocks *et al.*, 2002; Munga and Thresh, 2002). Symptoms include a blotchy chlorosis on the lower leaves of affected plants, brown streaky lesions on green stem portions and a sepioid to brown dry corky rot in tuberous roots (Nichols, 1950). Losses occur primarily from the spoilage of roots resulting from the dry rot, but in severe cases, dieback of the stems may also occur leading to reduced tuberous root production (Hillocks *et al.*, 2001). There have been recent reports of the occurrence of CBSD further west in western Democratic Republic of Congo (Mahungu, unpublished data), which if verified, would represent a substantial extension of the known distribution, and significantly raise the economic significance of the disease.

Characterization and diagnostics. The first distribution map of CMGs in Africa was developed from virus diagnoses using serological techniques (Swanson and Harrison, 1994). Monoclonal antibodies were developed which when used with triple antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) protocols could detect and differentiate between most isolates of African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV) (Ogbe *et al.*, 1996; 1997). The development and use of DNA-based diagnostic protocols using the polymerase chain reaction (PCR), however, was instrumental in showing the potential unreliability of serology-based diagnostics. Firstly, PCR techniques coupled with sequencing showed that the virus associated with the severe CMD epidemic in Uganda was a recombinant hybrid, in which a portion of the coat protein gene of the DNA A of ACMV was recombined with the rest of the DNA A

of EACMV (Zhou *et al.*, 1997). This strain became known as the Uganda variant of EACMV (EACMV-UG). Secondly, the new techniques also revealed the widespread occurrence of mixed virus infections, hitherto undistinguishable by serological methods. As the new diagnostics have become more widely practised, and sequencing has become quicker and cheaper, the amount of information available on the nature and organization of the bipartite genome of the CMGs has increased substantially. Six species of CMG are now recognised including ACMV, EACMV, South African cassava mosaic virus (SACMV) and three other EACMV-like species (Fauquet and Stanley, 2003). CMGs are revealed to be a highly complex, dynamic and adaptable group of viruses which would seem to explain their sustained and increasing success in infecting cassava in Africa.

Although there were unconfirmed reports of the aetiology of CBSD from various groups dating back to the 1970s, it was not until almost 70 years after the first description of the disease that the causal virus was definitively identified as cassava brown streak virus (Monger *et al.*, 2001a). Relatively insensitive serological diagnostic methods for the uncharacterized virus(es) associated with CBSD had been developed during the 1980s (Lennon *et al.*, 1986). However, following the characterization of the virus (Monger *et al.*, 2001a), which made use of reverse transcriptase-PCR (RT-PCR) and cloning technology in sequence determination, it became possible to develop much more sensitive RT-PCR-based diagnostic protocols (Monger *et al.*, 2001b). These have been used successfully to detect CBSV even in young symptom-free leaves of diseased plants, highlighting their sensitivity. Unlike CMGs, available sequence information on isolates of CBSV suggests that there is limited variability, and all isolates so far examined, albeit small in number, have had sequence homologies of greater than 90% (G. Foster, unpublished data). Very little information is currently available, however, and a much greater range of isolates from the diverse locations in which

CBSV occurs will need to be characterized before more definitive statements can be made about CBSV variability.

Transmission and epidemiology. The whitefly *Bemisia tabaci* (Gennadius) was recognised as being the likely vector of CMGs from some of the earliest work on CMD, and this suspicion was confirmed experimentally as early as the 1930s (Kufferath and Ghesquière, 1932). Later studies provided more detail on the characteristics of the transmission process (Chant, 1958) and it was demonstrated that CMGs were transmitted persistently, with a minimum inoculation period of 10 minutes, and that the virus could be retained for at least nine days (Dubern 1979; 1994). Recent studies have compared transmission of different CMG species by different geographical populations of *B. tabaci* and shown that differences were relatively insignificant (Maruthi *et al.*, 2002). The corollary of this is that the most important determinants of patterns of virus spread in the field are *B. tabaci* abundance and the amount of virus inoculum. As a result of the persistent nature of CMG transmission by *B. tabaci*, external inoculum sources have the greatest bearing on the pattern of virus spread in initially CMD-free fields (Fargette *et al.*, 1990). A characteristic of the spreading 'front' of the CMD pandemic has been the co-occurrence of super-abundant populations of *B. tabaci* and a high frequency of severely diseased mixed ACMV+EACMV-UG infected plants (Harrison *et al.*, 1997). ACMV and EACMVs have been shown to interact synergistically in mixed infections (Harrison *et al.*, 1997; Fondong *et al.*, 2000; Pita *et al.*, 2001) and there is also preliminary evidence for similar positive interactions between *B. tabaci* and severely CMD-diseased cassava plants (Colvin *et al.*, 1999). A further key factor in the propagation of the CMD pandemic is the mobility of *B. tabaci* populations, and individual adults can fly distances of at least 7km (Byrne and Blackmer, 1996). The combination of an abundant and mobile vector, efficient transmission

mechanisms and the year round presence of the cassava crop in most areas where it is grown make for a very effective epidemiological system which lies at the heart of the success of the CMGs in Africa.

CBSD has been shown to spread naturally under field conditions (Nichols, 1950) and relatively steep gradients of spread have been described (Hillocks *et al.*, 1999). Attempts have been made to identify the vector, and most studies have tested the whiteflies, *B. tabaci* and *Bemisia afer* Priesner and Hosny. *B. tabaci* would seem to be the most likely candidate since other ipomoviruses are transmitted by this insect. All transmission efforts with *Bemisia* spp. have so far failed to give positive results, however, and a key facet of future research into CBSV will be to undertake comprehensive studies targeted at identifying the vector.

Management. Approaches developed for the management of the virus diseases of cassava are typical of those used for many virus diseases of crop plants. Greatest attention has been directed towards the development of virus resistance, although significant efforts have also been made to identify crop management and phytosanitation practices that provide control. Resistance breeding programmes for both CMD and CBSD were initiated in what is now eastern Tanzania in the 1930s (Jennings, 1957). The most successful approach for CMD involved interspecific crossing with the wild relative, *Manihot glaziovii* Muell.-Arg., followed by multiple backcrosses with cultivated cassava. Progeny had good resistance to CMD, although root quality required further improvement. Parent material obtained from Tanzania then formed the basis for a major and uninterrupted breeding effort at IITA, which ran from 1970 to the present day. The multigenic resistance provided by the interspecific crosses has subsequently been augmented by the incorporation of new sources of resistance identified from local West African landraces. Some of the most recently developed varieties combine virtual

immunity to CMD with excellent agronomic and organoleptic characteristics. These now form the basis for CMD management programmes throughout the continent. Both *M. glaziovii* and *M. melanobasis* Muell.-Arg. were used in early efforts to develop resistance to CBSD (Jennings, 1957), with a certain amount of success, but following the termination of the Tanzania-based cassava breeding effort in the late 1950s, there was no further work on breeding for CBSD resistance until a major new IITA-led programme was initiated in 2001. CBSD resistance has also been identified as a trait for which there is good potential for the development of transgenic resistance, and new research initiated in 2003 aims to address this. In the current absence of good sources of CBSD resistance, on-going management programmes in coastal East Africa, Malawi and Mozambique are promoting the dissemination of local landraces identified as tolerant to CBSD (Hillocks *et al.*, 2002).

Phytosanitation has long been advocated as a means of controlling both CMD and CBSD, but the two principal elements, roguing and selection of disease-free planting material, are rarely practised, and clear guidelines on their use still remain to be developed. Crop management approaches such as intercropping, protecting susceptible with resistant varieties and isolation have all been proposed as possible additional control measures, but clearcut data on their effectiveness as CMD or CBSD control measure in the farm situation have yet to be presented. Studies of local landraces in Uganda have shown that cassava plants initially infected with mild strains of CMGs grow and yield better than initially CMD-free plants, suggesting the occurrence of a form of mild strain protection (Owor, 2002). Further research will be required, however, both to understand the mechanisms underlying this phenomenon and to identify ways in which it might be enhanced for the management of CMD in local landraces.

The development and deployment of virus resistance is likely to remain the primary tactic

used in the control of the two principal virus diseases of cassava for the foreseeable future. However, a range of alternative and potentially complementary methods do exist, and the challenge in the years ahead will be to develop an integrated approach to control that combine these elements into a sustainable strategy that is both effective and fits in with the requirements of farmers.

Virus Diseases of Sweetpotato

Introduction. Although sweetpotato was, like cassava, introduced to Africa from the Americas in the sixteenth century, it appears (despite less scientific attention) to be affected by a wider range of viruses. The most common, occurring throughout Africa, is sweetpotato feathery mottle virus (SPFMV) (*Potyviridae: Potyvirus*). Like other potyviruses, SPFMV is transmitted in the non-persistent manner by a wide range of aphid species. It causes either mild (typically purple or yellow ringspots or mottling on older leaves) or no symptoms in sweetpotato when infecting alone. Both the common (C) and the russet crack (RC) strains of SPFMV have been identified in Africa (Karyeija *et al.*, 1998). The second most common yet economically most important virus is Sweetpotato chlorotic stunt virus (SPCSV) (*Closteroviridae: Crinivirus*). It is transmitted in the semi-persistent manner by *B. tabaci*, which is common on sweetpotato. It may cause mild stunting and yellowing when infecting sweetpotato alone (Gibson and Aritua, 2002). However, its main economic damage results from its ability to break resistance to SPFMV (Karyeija *et al.*, 2000a), enabling SPFMV to spread and multiply in sweetpotato plants and reach titres up to a thousand-fold higher than when it infects alone (Karyeija *et al.*, 2000b). SPFMV does not, however, synergise SPCSV. The synergy of SPFMV by SPCSV also enables SPFMV to be acquired and transmitted more readily by aphids (Aritua *et al.*, 1998b) and results in the severe disease known as sweetpotato virus disease (SPVD), characterised by severe stunting and

distortion, vein-clearing and/or chlorotic mosaic to the leaves. Affected plants generally have a storage root yield less than 70% that of unaffected plants and many of the roots produced are small and unmarketable. SPVD appears to occur throughout sub-Saharan Africa. Two strains of SPCSV distinguishable serologically as well as by nucleic acid analyses have been found in Africa: SPCSV_{WA} occurring in countries along the Atlantic Ocean and SPCSV_{EA} in countries along the Indian Ocean and in more central countries such as Uganda and Zambia (Hoyer *et al.*, 1996; Gibson and Aritua, 2002). Other viruses found in Africa include further members of the Potyviridae, including sweetpotato mild mottle virus (SPMMV), sweetpotato virus Y and sweetpotato virus G. Sweetpotato chlorotic fleck virus and sweetpotato caulimo-like virus have also been found. Their distribution is unclear and, though they may be locally common, it is unclear whether any cause appreciable economic damage. Cucumber mosaic virus (CMV) has also been reported.

Diagnosis of sweetpotato viruses. Graft-inoculating scions of suspect sweetpotato to *Ipomoea setosa* Kerr. provides a detection system for most sweetpotato viruses (though not a specific diagnosis) as all except perhaps CMV cause symptoms in test plants of this species. It is perhaps the most sensitive technique available, though limited by the partial systemicity of viruses such as SPFMV when infecting alone. Panels of antisera against viruses infecting sweetpotato are also available from the International Potato Center in Lima, Peru, and enzyme-linked immunosorbent assays (ELISA) are available for relatively sensitive detection and precise diagnosis. Several of the viruses have also been sequenced allowing polymerase chain reaction (PCR) tests to be developed.

Epidemiology of SPVD. Sweetpotato is traditionally propagated in Africa by foliar cuttings taken from mature crops or from crops resprouting from storage roots following

rainfall after prolonged drought. Consequently, farmers have the opportunity to inspect the foliage of, and reject, abnormal plants including SPVD-affected ones as sources of cuttings. This process usually ensures that cuttings are free from SPCSV apart from those obtained from recently-infected, asymptomatic parent plants. SPFMV, having more-or-less unnoticeable symptoms, is not similarly restricted but it appears that it is only partially systemic in many cultivars so only a minority of cuttings may be infected (Gibson *et al.*, 1997).

There is no evidence that wild plants are a common source of either SPFMV or SPCSV although a few *Ipomoea* species growing wild in Africa have been shown to be infected rarely with SPCSV and SPFMV. Like CMD, the rate of spread of SPVD into unaffected crops has been shown experimentally to be determined by the numbers of adult *B. tabaci* infesting crops and the numbers of SPVD-affected sweetpotato plants in the vicinity (Aritua *et al.*, 1999). SPFMV is itself carried into new crops in many of the cuttings and, aided by the high titres it reaches in dually-infected plants, appears to spread rapidly in the presence of SPCSV. Spread of SPCSV is generally the factor determining the incidence of SPVD and, perhaps because whiteflies transmit SPCSV semi-persistently (for only a few hours or at most for a day following acquisition), spread is predominantly from nearby source plants.

Control of SPVD. Since resistance to SPFMV is broken by infection with SPCSV, resistance to SPVD is based on resistance to infection by SPCSV. Varieties of sweetpotato differ widely in their susceptibility to SPVD: cultivars imported from the Americas for other valuable genetic characters tend to be extremely susceptible whereas some African landraces are extremely resistant – though immunity has not been recorded. Resistance to SPVD generally seems to be inversely related in landraces to yielding ability or other beneficial attributes (Aritua *et al.*, 1998a). Consequently, farmers may have to make

compromises between these beneficial attributes and adequate SPVD resistance – and such compromises are another important means by which SPVD causes economic loss. Modern breeding has, however, been able to identify genes for resistance (Mwanga *et al.*, 2002a & b) and to select high-yielding resistant varieties such as NASPOT 1, released in Uganda by the Namulonge Agricultural and Animal Production Research Institute.

In addition to the use of resistant varieties, the main way by which African farmers control SPVD is through careful selection of unaffected plants as sources of cuttings for their new crops. Careful questioning has, however, revealed that most farmers in East Africa do not realise that SPVD is a disease caused by viruses. In particular, they are not aware that whiteflies spread the virus that triggers it – although farmers that have received training in the control of CMD, especially those affected by the CMD pandemic, quickly appreciate it. Because most spread of SPCSV by whiteflies occurs over a short distance, roguing diseased plants in young crops to remove infection sources and planting new crops isolated from older ones have been shown experimentally to reduce spread considerably (Gibson *et al.*, 2003). Consequently, following careful explanation and demonstration of how SPVD is spread, local phytosanitation is being evaluated together with East African farmers as a practical method of controlling SPVD.

Virus Diseases of Yam

Introduction. Most edible yam species are vegetatively propagated using planting setts, tuber pieces, aerial tubers, bulbils and, to a lesser extent, tissue culture. Where viruses infect the mother plants, they will be transmitted in the vegetative propagules and there will therefore be a tendency for build-up of virus diseases in the germplasm. The symptoms caused by viruses infecting yams range from almost symptomless infection or mild chlorosis / mottling to severe mosaics, leaf distortion, stunting and occasionally

dieback, depending on the virus. Infection by more than one virus can induce more severe symptoms. Host genotype also influences symptom expression and, where the growing conditions are sub-optimal, symptom expression is usually more severe.

Characterization and diagnostics. Yam mosaic virus (YMV) (*Potyviridae: Potyvirus*) is found in almost all regions throughout the world where yams are grown. YMV induces chlorotic flecking, green-banding, severe leaf chlorosis and leaf distortion. In *D. rotundata-cayenensis* and *D. esculenta*, the virus is widespread in West Africa and has been detected occasionally in *D. alata* in Nigeria (Hughes, unpublished data). YMV is mechanically transmissible to indicator plant species (e.g. *N. benthamiana*), which can be used for diagnosis of virus infection where other tools are not available (Brunt *et al.*, 1997). Both monoclonal and polyclonal antibodies are available which can be used in either TAS-ELISA or protein A-sandwich (PAS)-ELISA for identification of YMV in Africa. YMV can also be detected by tissue blotting of cut tubers, PCR using specific primers as well as the more broad-spectrum primers against the *Potyvirus* genus.

Dioscorea alata virus (DaPV), (*Potyviridae: Potyvirus*) is probably coincident with the culture of *D. alata* (Hughes, 1986; Mumford and Seal, 1997; Odu *et al.*, 1999; Olatunde, 1999), and is commonly found in West Africa. It causes mild or inconspicuous mottling, veinal necrosis, occasional vein-banding, leaf distortion and severe chlorosis (Odu *et al.*, 1999). DaPV can be detected using polyclonal antisera (Hughes, 1986; Odu *et al.*, 1999).

Other potyviruses have also been identified infecting *Dioscorea* species. *Dioscorea dumetorum virus* (DDV), (*Potyviridae: Potyvirus*) has been detected by ELISA in *D. alata* from Nigeria (Hughes *et al.*, 1997). ‘Universal’ potyvirus monoclonal antibodies are not appropriate for detecting potyviruses in yam sap extracts. False values are obtained in ELISA which may be a result

of the composition of the host sap. However, it appears that the ‘universal’ antibodies can be effective when the virus has been transmitted to alternative herbaceous plant species.

A badnavirus, probably *Dioscorea alata virus* (DaBV), reported by Phillips *et al.* (1999) and Briddon *et al.* (1999) is associated with severe leaf distortion, crinkling and mottling in *D. alata* in Nigeria. The virus is mechanically transmissible to several *Dioscorea* species. ELISA using polyclonal antibodies can be used to detect DaBV. Immunosorbent electron microscopy (ISEM) can also be a useful tool to detect and identify the virus in its natural host. While specific primers are available for a West African strain of the virus, because of the high level of virus variability, the primers only work with some isolates (Briddon *et al.*, 1999).

Cucumber mosaic virus (CMV) (*Bromoviridae: Cucumovirus*) infects *D. alata*, *D. trifida* (Fauquet and Thouvenel, 1987; Migliori and Cadilhac, 1976) and *D. rotundata* (Dongo, pers. com.) in West Africa. Symptoms caused by CMV can include severe mosaic, leaf chlorosis, stunting and leaf distortion. ELISA can be used for detection of CMV using polyclonal antisera. Immunocapture (IC)-PCR can also be used and primer pairs are available which can detect CMV isolates that infect *Dioscorea* spp. (Brunt *et al.*, 1997).

Dioscorea mottle virus (DMoV) infects *D. alata* in Nigeria (Hughes *et al.*, 1997). Symptoms include mild chlorosis, mottling and necrosis. This virus is only partially characterised but has been found in samples from the yam belt of Nigeria (Hughes, unpublished data). DMoV is mechanically transmissible from *D. alata* (Hughes *et al.*, 1998) and therefore transmission to indicator species (*Vigna unguiculata*, *Glycine max*, *Chenopodium murale*, *C. amaranticolor* and *C. quinoa*) can be used for diagnosis. Polyclonal antibodies are also available and these can be used in PAS-ELISA to detect the virus.

Transmission and epidemiology. Aphids are the most important insect vectors of yam viruses. A range of aphids (*Aphis fabae*, *A. craccivora*, *Rhopalosiphum maidis*, *Toxoptera citricidus*, *Myzus persicae* and *A. gossypii*) transmits YMV (Brunt *et al.*, 1997) although the relative importance of individual aphid species as vectors in the field is unknown. *A. craccivora* and *R. maidis* also transmit DaPV (Odu *et al.*, 1999). CMV is efficiently transmitted in nature in the non-persistent manner by a wide range of aphid species (including *A. craccivora* and *M. persicae*). Mealybugs may play an important role in the transmission of DaBV. *Planococcus citri* (Briddon *et al.*, 1999) transmits DaBV and several other mealybug species have been found in association with yams in the field, but their role in transmitting this group of viruses is unknown. The natural insect vector of DMoV is not known.

Although vector transmission occurs and may play an important role in the epidemiology of yam viruses, one of the most important means of transmission is through vegetative propagation. As yams are traditionally multiplied through tuber sets or pieces, if the mother plant was virus infected, any tubers that are produced will also be infected with the same viruses, and consequently so will any progenies derived from these tubers. Observations in farmers' fields suggest that the larger tubers (most likely derived from healthy mother plants) are more likely to be sold or consumed, while the smaller tubers, which may have been derived from infected mother plants, may be used for propagation. As with all vegetatively propagated species, virus infection of the propagules often leads to slower germination and reduced vigour in the young plants. Continued propagation of virus-infected germplasm can lead to a build-up of more than one virus in the plants as a result of vector transmission in the field (or perhaps as a result of mechanical transmission when the planting sets are cut) thus causing significantly reduced vigour and reduced yields.

Management. Yam viruses are transmitted vegetatively from one generation to the next and from one season to the next using conventional vegetative propagation methods. An important method for controlling the diseases is therefore to use healthy planting materials. Farmers can improve the health status of their crops by ensuring that only propagules taken from yams that looked healthy during the previous growing season are used. Where resources are available it may be possible to use virus-tested plantlets produced in tissue culture. Where it is not feasible to use these plantlets because of their requirements for transplanting and 'hardening' before they can be planted in the field, mini-tubers can be produced in vector-proof conditions and distributed to seed yam producers for further multiplication and distribution.

Discussion and Conclusions

Viruses of the three principal root and tuber crops grown in sub-Saharan Africa comprise some of the most important constraints to their production. They are relatively more important than other groups of pests and diseases in part as a result of the importance of vegetative propagation which typically represents the most important source of infection in new plantings of cassava, sweetpotato and yams. All three crops are infected by a diversity of viruses, although cassava has only two groups that cause economic damage (Table 1). The two virus groups that affect cassava are largely confined to Africa, in contrast to sweetpotato and yams where most of the viruses have worldwide distributions. The importance of Nigeria in the distribution of yam viruses reflects the fact that it produces significantly more yams than any other country in the world.

Recent research has revealed a range of mechanisms that are helping the cassava mosaic geminiviruses to evolve, as evidenced by the frequent occurrence of recombinants and pseudorecombinants. Variability

Table 1: Viruses identified as affecting cassava, sweetpotato or yams in Africa.

Virus	Acronym	Genus	Family	Vector	Distribution
Cassava*					
Cassava mosaic geminiviruses	CMGs	<i>Begomovirus</i>	<i>Geminiviridae</i>	Whiteflies	Mainly Africa
Cassava brown streak virus	CBSV	<i>Ipomovirus</i>	<i>Potyviriidae</i>	Unknown	Africa
Sweetpotato					
Sweetpotato feathery mottle virus	SPFMV	<i>Potyvirus</i>	<i>Potyviriidae</i>	Aphids	Worldwide
Sweetpotato chlorotic stunt virus	SPCSV	<i>Crinivirus</i>	<i>Closteroviridae</i>	Whiteflies	Worldwide
Sweetpotato mild mottle virus	SPMMV	<i>Ipomovirus</i>	<i>Potyviriidae</i>	Whiteflies	Mainly Africa
Sweetpotato chlorotic fleck virus	SPCFV	Unassigned	Unassigned	Unknown	Worldwide
Sweetpotato virus Y	SPVY	<i>Potyvirus</i>	<i>Potyviriidae</i>	Aphids	Worldwide
Sweetpotato virus G	SPVG	<i>Potyvirus</i>	<i>Potyviriidae</i>	Aphids	Worldwide
Sweetpotato caulimovirus	SPCaV	Unassigned	Unassigned	Unknown	Worldwide
Cucumber mosaic virus	CMV	<i>Cucumovirus</i>	<i>Bromoviridae</i>	Aphids	Worldwide
Yams					
Yam mosaic virus	YMV	<i>Potyvirus</i>	<i>Potyviriidae</i>	Aphids	Worldwide
Dioscorea alata virus	DaV	<i>Potyvirus</i>	<i>Potyviriidae</i>	Aphids	Worldwide
Dioscorea dumetorum virus	DDV	<i>Potyvirus</i>	<i>Potyviriidae</i>	?aphids?	Nigeria
Dioscorea alata bacilliform virus	DaBV	<i>Badnavirus</i>	<i>Caulimoviridae</i>	Mealybugs	Nigeria
Cucumber mosaic virus	CMV	<i>Cucumovirus</i>	<i>Bromoviridae</i>	Aphids	Worldwide
Dioscorea mottle virus	DMoV	Unassigned	Unassigned	Unknown	Nigeria

*Additional unassigned viruses recorded from cassava in one or a few locations only in Africa include: *Cassava Ivorian bacilliform virus*, *Cassava Kumi viruses*, *Cassava 'Q' virus* and *Cassava common mosaic virus* (Calvert and Thresh, 2002).

amongst viruses of both sweetpotato and yams suggests that these pathosystems are similarly dynamic. Sweetpotato is host to viruses transmitted both by aphids and the whitefly, *B. tabaci*, and significantly, the whitefly-borne crinivirus, SPCSV, and the aphid-borne potyvirus, SPFMV, interact synergistically to give rise to the severe disease condition of SPVD. Although similar intergenus interactions do not seem to occur in cassava or yams, synergism is an important feature of the interaction of different CMG species.

The similar environmental requirements of both cassava and sweetpotato mean that they are commonly grown together. Although *B. tabaci* occurs on both crops, it is significant that evidence suggests that these are distinct

biotypes that do not cross colonize (Legg, 1996). This has important implications for the development of 'banker crop' biocontrol approaches which use one or other of the crops to build up natural enemy populations to infest the other, since whilst natural enemies will move between the crops, the *B. tabaci* populations will not. Another important consequence of the frequent co-cultivation of these two crops is that where major losses occur to one, the other can be multiplied up as a substitute, a phenomenon that was an important feature of the management of the CMD pandemic.

All three of the root/tuber crops face major management challenges as a result of virus disease infection, and in all cases, host plant resistance has been developed as a key

control tactic. High levels of resistance to CMD have been developed through interspecific and local landrace crossing for cassava. Resistance will remain the key component in integrated control programmes set up to manage the acute epidemics associated with CMD and CBSD. The greater virus diversity, less acute damage and stronger reliance on vegetative propagation that characterize virus disease problems in sweetpotato and yams mean that a stronger emphasis is being placed on developing mixed management systems combining resistance with cultural methods, phytosanitation and seed health systems for yams. An additional challenge that faces those trying to develop and implement control programmes targeting virus diseases of root and tuber crops is the lack of awareness and understanding of these problems amongst farmers and agricultural extensionists. In the future, researchers will need to work closely with these groups in strengthening knowledge both through field-based training and in enhancing the quality and availability of training materials. Important synergies can be achieved in this work by considering the crops together, most particularly for cassava and sweetpotato where there are many commonalities in the virus problems and cropping environments.

Substantial progress has been made over the last decade in researching the viruses and virus diseases of the African root and tuber crops, and the benefits of the increased knowledge accrued are already being realised in countries where efforts have been targeted such as Nigeria, Ghana, Uganda and Tanzania. Much still remains to be done, however, and major research for development efforts will need to be sustained and strengthened over the next decade, if the virus diseases of these crops are to be effectively managed. Only if this is achieved will it be possible to realize the full potentials of these crops for the benefit of the hundreds of millions of sub-Saharan Africans who depend on them for their livelihoods.

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Reprise des recherches sur le manioc au Congo suite a la pandemic de la mosaïque africaine de manioc

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Résumé. A la suite des troubles, la République du Congo a connu, à partir de 1999, une recrudescence des maladies graves (mosaïque et bactériose) sur le manioc. La situation de la production de manioc a été gravement détériorée provoquant de grandes pénuries dans les grands centres de consommation urbains et dans certaines zones rurales. Une intervention de l'IITA soutenue par l'USAID a été orientée sur la lutte contre la maladie pandémique de la mosaïque en 2002 et 2003. Dans le cadre de cette intervention, un certain nombre d'activités ont été engagées, notamment la diversification et l'échange de germoplasme, la conduite des essais Tests/Evaluation en différentes zones écologiques, et, la multiplication des clones tolérants pour la mise à la disposition des paysans des boutures à planter. Les résultats préliminaires obtenus présentent des clones performants comme le clone 92/277 et méritent d'être renforcés par d'autres introductions et évaluation pour endiguer la mosaïque du manioc en Afrique centrale.

Introduction

Le manioc constitue la principale source de calories du Congo et couvre environ les deux tiers des superficies cultivées. Le manioc est consommé sous forme de féculent (foufou ou chikwangue) deux fois par jour en moyenne et à ce titre, on estime la consommation

moyenne par tête d'habitant et par an à 175 kg dans les villes et à 425 kg à la campagne. Il est également consommé sous forme de feuilles ou saka-saka qui constitue un apport substantiel en protéines. A la suite des troubles, le Congo a connu, à partir de 1999, une recrudescence des maladies graves (mosaïque et bactériose) sur le manioc. La situation de la production de manioc a été gravement détériorée provoquant de grandes pénuries dans les grands centres de consommation urbains et dans certaines zones rurales (Bani et Mapangou Divassa, 2000). Dans l'étude diagnostic réalisée sur le manioc en 1996, la mosaïque africaine est tout simplement citée parmi les contraintes au développement de la culture (Kani *et al.*, 1996). L'enquête diagnostique récente menée sur l'ensemble des dix départements du pays a montré que l'incidence a été forte en 2002 avec 82,1% de plantes portant la maladie (Ntawuruhunga *et al.*, 2002) et a augmenté en 2003 avec 86,7% (Ntawuruhunga, 2003). Pour lutter contre les maladies du manioc au niveau du pays, un certain nombre d'activités ont été engagées avec l'aide de l'Institut International d'Agriculture Tropicale (IITA), notamment la diversification et l'échange de germoplasme, la conduite des essais Tests/Evaluation en différentes zones écologiques, et, la multiplication des clones tolérants pour la mise à la disposition des paysans des boutures à planter. Afin de connaître et d'endiguer l'impact de la maladie de la

mosaïque africaine, les clones IITA introduits au Congo en 1992 ont été utilisés dans des essais d'évaluation des effets de la mosaïque africaine au niveau de 3 sites couvrant notamment la région des plateaux batékés, soit Odziba dans le Pool nord, Lékana dans les Plateaux et Ewo dans la Cuvette ouest.

Matériels et Méthodes

Au total 17 clones ont été sélectionnés sur leur possible résistance à la mosaïque, soit : 92/519, 92/265, 92/121, 92/269, 92/283, 92/167, 92/277, 92/157, 92/130, 92/647, 92/263, 92/147, 92/271, 92/Inconnu, 92/144, 92/106, 92/245. Les clones ont été plantés sur un dispositif blocs de Fisher complètement randomisés avec 3 répétitions à Odziba et Lékana et 2 répétitions à Ewo. Les parcelles unitaires sont de 3 lignes de 11 mètres avec un écartement de 1 mètre entre les pieds et 1 mètre entre les lignes. Chaque parcelle est séparée de l'autre de 2 mètres. Les boutures de 25 cm de long sont plantées enfouies à plat. Les essais installés à Odziba et à Lékana sont sur site de savane et ceux de Ewo sur site de forêt. Les évaluations à la mosaïque africaine ont été faites par intervalles de 3 mois et les récoltes à 12 mois. La maladie de la mosaïque a été suivie et observée sur chaque pied pour chaque clone. La bactériose vasculaire a également été observée et a reçu une cote globale par parcelle de l'essai. Les analyses statistiques concernant les observations réalisées sur l'évaluation de la pression de la mosaïque et les récoltes sont faites avec le logiciel Statitcf.

Résultats

La mosaïque dans les plateaux batékés. Les observations faites à 3 mois (Tableau 1) indiquent que les clones 92/106, 92/130, 92/277 et 92/647 ne présentent pas de symptômes de mosaïque à Odziba. A Lékana, l'ensemble des clones montre une sensibilité à la maladie. Toutefois les clones 92/245 et 92/277 ne portent que de symptôme de faible gravité avec une incidence faible respective de 31 %

et 1,45 %. A Ewo seul le clone 92/647 a résisté à la maladie toutefois avec une sévérité de 2 et une incidence faible de 14, 26 %. Les résultats obtenus sur chaque site indiquent qu'à Odziba les clones 92/130, 92/277, 92/106 et 92/647 sont plus tolérants à la maladie ; à Lékana les 92/277, 92/245 et 92/106 résistent et à Ewo uniquement le clone 92/647 présente une bonne tolérance à la maladie. On observe ainsi que la pression de la maladie est plus forte à Ewo qu'à Lékana et encore plus forte qu'à Odziba. La maladie de la mosaïque présente une faible incidence à Odziba. Sur ce site, à 3 mois 11,1% de clones ne sont pas attaqués par la mosaïque et 38,8% de clones portent la maladie avec une sévérité moyenne (côte 3) contre 50.2% à Lékana et 43.7% à Ewo. (Tableau 2).

A Odziba beaucoup plus de plantes ne portent plus de symptômes de la maladie à 6 mois. On recense 55,5% de clones qui ne présentent pas la maladie (Tableau 2) contre seulement 11,1% de clones à 3 mois. Ce phénomène connu de guérison des plantes se retrouve sur les sites de Lékana et de Ewo. Beaucoup de plantes ne montrent plus de symptômes de la maladie à 6 mois à Lékana (43.7% de clones) et à Ewo (6,2% de clones). La maladie évolue dans le même sens au niveau des 3 sites. On remarque en effet qu'à 9 mois il y a un léger regain de gravité de la maladie sur tous les sites. Seulement 44,4% de clones ne portent plus de symptômes de la maladie à Odziba, 31,2% de clones à Lékana et, cependant à Ewo tous les clones présentent des symptômes.

La pression de la bactériose. La bactériose vasculaire a également été observée. Presque inexistante de 0 à 6 mois , à 9 mois elle a été notable. L'évolution de la gravité de la maladie a été rapide dans la période de 9 à 12 mois. Contrairement à la mosaïque qui, dans une parcelle contaminée a permis l'existence des plantes sans symptômes, la bactériose vasculaire, lorsqu'elle s'est déclarée, a été présente au même degré sur toutes les plantes de la parcelle infectée. Le tableau 3 enregistre les résultats sur la bactériose sur les 3 sites.

On constate qu'à Odziba 11% de clones seulement ne présentent pas des symptômes de la maladie et 33,3% sont attaqués avec une faible sévérité , par contre 55,4% de clones montrent des symptômes graves (côtes 4 et

5) avec die-backs. A Lékana et à Ewo tous les clones sont ravagés par la bactériose. On trouve 6,2% de clones faiblement attaqués et 18,7% moyennement attaqués à Lékana contre 75% de clones avec symptômes graves. Par

Tableau 1: Sévérité et incidence de la maladie à 3 mois sur les 3 sites.

Clones	ODZIBA		LEKANA		EWO	
	Sévérité	Incidence (%)	Sévérité	Incidence (%)	Sévérité	Incidence (%)
106	1,5 a	4,4 ab	2 ab	76,67 d		
121	3 c	80,68 h	3 c	68,13 d		
130	1 a	0 a	2,5b	2,72 a	3 c	49,68 a
144	2 b	7,43 c	2,5 b	10,72 a	3,5 d	98,27 c
147	3 c	18,19 d	2,5 b	16,46 ab	2,5 b	62,3 b
157	3,5 cd	10,13 bc	3,5 c	17,67 b	3,5 d	45,69 a
167	3 c	55,98 g	3 c	56,8 d	3 c	88,75 bc
245	2 b	2,31 a	1,5 a	31 bc	3 c	69,03 b
263	-	-	3,5 c	38,11 c	-	-
265	-	-	3,5 c	26,42 b	3 c	69,33 b
269	2,5 b	15,77 cd	-	-	3 c	50,46 ab
271	4 e	100	4 d	96,97 e	3,5 d	100 c
277	1 a	0 a	1,33 a	1,45 a	3 c	65,95 b
283	2,5 b	3,19 a	-	-	-	-
519	2,5 b	6,5 b	3 cd	6,27 a	3 c	25,15 a
647	1,5 a	1,07 a	-	-	2 a	14,26 a
Inconnu	3 c	5,96 b	4 cd	60,71 d	4 e	86,83 b
MM86	4 e	27,06 e	4,33 e	25,94 b	4,5 f	100 c
NGUEBANA	4 e	37,98 g	-	-	4 e	-
OYOUROU	-	-	-	-	4 e	62,27 b
YAKA YAKA	-	-	-	-	4 e	100 c
NKAAKA	--	-	-	-	-	-
CV	32,74	36,64	33,4	54,43	10	18,42
PPDS	0,59	5,88	0,73	15,06	0,27	41,85

Seuil = 5%.

Tableau 2: Incidence de la maladie selon les sites à 3, 6 et 9 mois.

Sévérité	Odziba			Lékana			Ewo		
	3 mois	6 mois	9 mois	3 mois	6 mois	9 mois	3 mois	6 mois	9 mois
1	11,8	17,6	0	0	0	0	0	0	0
2	41,2	64,7	70,6	20	93,3	80	12,5	62,5	37,5
3	29,4	11,8	17,6	40	6,7	13,3	62,5	25	50
4	17,6	5,9	5,9	40	0	6,7	25	12,5	6,2
5	0	0	5,9	0	0	0	0	0	6,2

contre à Ewo, 100% de clones montrent des symptômes graves. Egalement comme pour la mosaïque, la pression de bactériose est plus forte à Ewo qu'à Lékana et encore plus forte qu'à Odziba.

Les rendements des clones en essai. Les résultats obtenus à Odziba donnent une supériorité de production en tubercules au clone 92/277 (20,4 t/Ha) (Tableau 4), secondé de loin par le clone 92/269 (15 t/Ha) puis le clone 92/147 (14 t/Ha). Pour Lékana le clone le plus productif est le clone 92/147 (18 t/Ha) suivi par le clone 92/277 (14,5 t/Ha) puis le clone 92/121 (13,9 t/Ha). A Ewo nous notons que le clone 92/277 est très productif (23,3 t/Ha) suivi par le clone 92/269 (22,6 t/Ha) puis le clone 92/245 (21,4 t/Ha). Bien qu'attaqué par la bactériose, le clone 92/167 avec 13,8 t/Ha est classé au troisième rang. On note également que des clones ne montrant pas des symptômes de mosaïque tels que les clones 92/106, 92/130, 92/277 et 92/647 à Odziba, ou des clones présentant des symptômes de faible gravité à Lékana comme 92/245 et 92/277 et à Ewo comme 92/647, seul le clone 92/277 s'est retrouvé parmi les 3 clones les plus productifs sur chaque site. Cependant les clones 92/106, 92/245, 92/519 et 92/647 ont présenté une production médiocre en tubercules. Avec une moyenne de 19,4 t/Ha sur les trois sites, le clone 92/277 (tableau 5) se place en tête des clones retenus pour la multiplication. Il est secondé de près par le clone 92/269 (18,8 t/Ha). La performance

du clone 92/245 à Ewo (21,4 t/Ha) montre que ce dernier produit mieux en zone de forêt.

Discussion

Sélectionné pour la résistance à la bactériose (Mabanza, 1980 ; 1986. Mabanza et Mingui, 1988) le clone MM86 a, à partir de 1985 remplacé les cultivars locaux développés par les paysans à Odziba et dans la région des Plateaux (Mabanza *et al.*, 1993). Il présente cependant un niveau faible de tolérance à la mosaïque africaine (Mabanza, 1987 ; Mingui et Mabanza, 1989 ; Mabanza et Mingui, 1998 a et b). Selon le diagnostic récent (Ntawuruhunga *et al.*, 2002 ; Ntawuruhunga, 2003) l'explosion de la mosaïque au Congo est due à la présence d'une nouvelle souche de virus très virulente appelée souche ougandaise, mais également à l'utilisation des boutures malades qui confirme une contamination par les boutures à 80% dans les plantations développées par les paysans. Les clones 92/106, 92/130, 92/277 et 92/647 ont présenté une bonne résistance à la mosaïque. Toutefois le niveau bas de production en racines amylacées prouve qu'un clone résistant n'est pas automatiquement productif s'il ne présente pas une bonne aptitude à l'accumulation des réserves amylacées racinaires sur le lieu de culture. D'autre part, bien que résistants à la mosaïque ils ont gravement été attaqués par la bactériose vasculaire. Par contre le clone 92/277 possède une tolérance élevée à la

Tableau 3: Incidence de la bactériose vasculaire au niveau des sites à 12 mois.

Site	Sévérité	1	2	3	4	5
Odziba	Clones attaqués	2	6	0	1	8
	Incidence (%)	11,8	35,3	0	5,9	47
Lékana	Clones attaqués	0	1	4	0	12
	Incidence (%)	0	5,9	23,5	0	70,6
Ewo	Clones attaqués	0	0	0	0	16
	Incidence (%)	0	0	0	0	100

mosaïque et manifeste une souplesse d'adaptation dans la zone des plateaux batékés, aussi bien en savane qu'en forêt. Il peut par conséquent servir de clone de référence pour tout travail, et ceci constitue un défi pour la recherche et le gouvernement du Congo.

Conclusion

Le travail réalisé à Odziba, Lékana et Ewo a dégagé au moins 3 clones que les paysans peuvent multiplier pour résoudre le problème de pénurie de manioc. Ces acquis doivent être capitalisés par la continuation des essais tests

Tableau 4: Mosaïque à 6 mois, bactériose à 12 mois et rendements (t/ha).

Clones	Odziba				Lékana				Ewo			
	SM6	IM6	CBB12	RDT	SM6	IM6	CBB12	RDT	SM6	IM6	CBB12	RDT
106	1	0	5	10,4	2	6,3	5	8,4	-	-	-	-
121	3	89,3	2	12,3	2	63,6	5	13,9	-	-	-	-
130	1	0	5	11	2	1,4	5	9,9	2	53,95	5	14,5
144	2	6	5	8,3	2	12,7	5	5,2	2	89,45	5	8,5
147	2	22,8	2	14	2	13,2	3	18,07	3	76,4	5	12,2
157	2	10	5	11,4	2	26,4	5	6,3	2	62,2	5	7,6
167	2	38,4	4	13,8	2	52,6	3	13,8	3	92,6	5	16,1
245	2	2,2	2	9,5	2	8,2	5	12,3	2	67,4	5	21,4
263	-	-	-	-	2	31,7	5	9,7	-	-	-	-
265	-	-	-	-	2	39,6	5	9,9	2	86,35	5	16,4
269	2	16,47	2	15	-	-	5	-	2	-	5	22,6
271	4	100	5	6,1	3	100	5	8,5	3	93,7	5	10,8
277	1	0	2	20,4	2	2,4	3	14,5	2	48,95	5	23,3
283	2	2,07	5	11,6	-	-	-	-	-	-	-	-
519	2	5,33	5	8,7	2	4,5	5	6,7	2	41,25	5	15,1
647	2	1,03	5	6,2	-	-	-	-	2	7,8	5	17,4
Inconnu	2	7,1	2	13	2	55,7	5	6,3	3	97,35	5	6
MM86	2	45,7	1	-	2	44,5	3	8,6	4	100	5	-
Nguebana	3	70,7	1	-	-	-	2	14,8	-	-	-	-
Oyourou	-	-	-	-	-	-	-	-	3	71,0	5	-
Yakayaka	-	-	-	-	-	-	-	-	4	100	5	-
Nkaaka	2	30,4	-	-	-	-	-	-	-	-	-	-
Moyenne production site (t/ha)	11,4				10,43				14,76			

SM6 : Sévérité de la mosaïque à 6 mois.

IM6: Incidence de la mosaïque à 6 mois.

CBB12: Sévérité de la bactériose vasculaire à 12 mois. RDT: Rendement tonnes/hectare.

Tableau 5: Rendements des clones retenus pour les multiplications sur les différents sites.

Sites	92/277	92/147	92/269	92/Inconnu	92/121	92/167	92/245
Odziba	20,4	14	15	13	12,3	13,8	9,5
Lékana	14,5	18,07	-	6,3	13,9	13,8	12,3
Ewo	23,3	12,2	22,6	6	-	16,1	21,4
Total	58,2	44,27	37,6	25,3	26,2	43,7	43,2
Moyenne	19,4	14,7	18,8	8,4	13,1	14,5	14,4

à travers un grand programme d'évaluation d'une base assez large de germoplasme amélioré afin d'identifier des clones qui présentent une meilleure combinaison de résistance contre la mosaïque et la bactériose et une accumulation performante des réserves amylacées racinaires.

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Evaluation agronomique et économique du système de production améliorée des semenceaux d'igname à partir des minifragments au Centre Bénin

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Résumé. Une étude a été conduite dans la région des savanes du Bénin dans les zones dégradées et moins dégradées. L'étude avait pour but d'identifier le mode de pré-germination approprié pour la technique de minifragmentation et d'évaluer les aptitudes agronomiques et économiques des variétés d'igname à cette technique. Les résultats de l'étude ont révélé des réponses variables selon les variétés. Le mode de pré-germination à même le sol sous abri (arbres) apparaît plus indiqué par rapport à l'usage du panier pour la technique de minifragmentation des semenceaux. Des pertes sensibles de minissets étaient observées dans les strates inférieures des paniers (du deuxième strate au quatrième strate). Aucun effet substrat n'a été observé pendant la phase de pépinière ni après transplantation des semenceaux en champs paysans. Parmi les variétés testées appartenant au complexe *Dioscorea cayenensis-rotundata*, la variété *Gangni* à deux récoltes présentait une bonne aptitude agronomique à la technique de minifragmentation par rapport à *Kokoro* (à une récolte) et *Yanabo* (à deux récoltes). La variété *Gangni* affichait sur le site de Akpéro (site moins dégradé) une production de 9,45 t ha⁻¹ contre 5,58 t ha⁻¹ et 4 t ha⁻¹ respectivement pour *Kokoro* et *Yanabo*. Sur le site de Miniffi (site dégradé), le rendement était de 3,1 t ha⁻¹ pour *Gangni* et 0,82 t ha⁻¹ pour *Kokoro* avec une différence significative au seuil de 5%. Les rendements et les composantes de rendements étaient relativement élevés à Akpéro liés à une fertilité plus élevée des sols.

La baisse de rendements en général observée était liée au retard de pluie qui a conduit au retard de transplantation des semenceaux d'igname affectant ainsi leur cycle de production. La production traditionnelle des semenceaux d'igname pour les variétés *Gangni* et *Yanabo* est rentable dans les nouvelles défriches (système de défriche brûlis) avec un ratio bénéfice coût de 1,5 unités. Elle n'est pas rentable pour *Kokoro*. Le système amélioré de production d'igname à partir des minifragments dans les anciennes défriches (champ traditionnel en culture continue) est également rentable pour les variétés *Gangni* et *Yanabo* avec un ratio bénéfice coût de 1,5 comparable à celui observé dans les nouvelles défriches. Les variétés *Gangni* et *Yanabo* présentent une valeur marchande intéressante et sont économiquement attractives pour la technique de production améliorée des semenceaux d'igname. Sur la base des résultats obtenus, il serait souhaitable de recommander les techniques d'amélioration de la fertilité des sols dans les anciennes défriches avec l'utilisation des légumineuses herbacées ou arbustives. Des recherches méritent d'être menées dans le domaine de l'organisation de la filière, de la production jusqu'à la commercialisation des semenceaux d'igname. Quelques approches sont proposées dans le présent document.

Abstract. A study was carried out in Savannah area of Benin in degraded and less degraded soil. The goal of study was to identify the appropriate mode of nursery and

evaluate (agro-economic assessment) the minissetts production system. Three varieties of (*Dioscorea cayenensis-rotundata* complex) such as *Gangni*, *Yanabo* (varieties of two harvestings), *Kokoro* (variety of one harvesting) and two support (soil and basket) containing sandy soil or sawdust were used at nursery phase. After germinating, the minissetts were transplanted on farmers' fields. The results showed variables responses for varieties. The germinating mode on the soil (under trees) seems to be adequate for the minissetts technique compared to the use of basket. The sensitive loss of minissetts was observed on inferior steps of the baskets (from 2 to 4 steps). No significant effect of substrate was observed during the germinating and transplanting phases. Among varieties tested, *Gangni* expressed interesting agronomic aptitude for minissetts technique compared to the others. In less degraded soil (Akpéro), *Gangni* tubers yield raised 9,45 t ha⁻¹ against 5,58 t ha⁻¹ and 4 t ha⁻¹ for *Kokoro* and *Yanabo* respectively in traditional continuous cropping system. At Miniffi, degraded soil, the tuber yield was significant (5%) ranged 3,1 t ha⁻¹ and 0,82 t ha⁻¹ for *Gangni* and *Kokoro*. The yield and its components are relatively higher in less degraded soil related to the initial soil fertility level. In general, yields are low because of rainy fall perturbation which led to the late of transplanting and the loss of minissetts; this affecting production cycle. Traditional dominant system of yam seed production in slash and burn system (shifting cultivation system) was profitable for *Gangni* and *Yanabo* varieties with benefit cost ratio of 1,5 but not profitable for *Kokoro*. The improved seed yam in traditional continuous cropping system was equally profitable for *Gangni* and *Yanabo* varieties with benefit cost ratio of 1,5 compared to the result observed in slash and burn system. Both varieties are economically attractive for minissetts technique. On the basis of these results, techniques for improving soil fertility with the use of herbaceous or woody legumes are to be recommended in traditional continuous

cropping system. Researches have to be focussed also on the organisation mechanism including production and commercialisation for promoting the sector. Some approaches are proposed in this document.

Introduction

L'igname constitue l'une des principales cultures dans la région des savanes. Une difficulté importante dans la production de la culture d'igname concerne le matériel de plantation, à savoir les semenceaux d'igname qui ne sont pas toujours disponibles en quantité et en qualité. Ils sont en outre coûteux. Par exemple la variété *Lamboko* (*Dioscorea rotundata*) coûte 75 à 150 F CFA par semenceau dans la région des collines. Ce qui demande un investissement de 300000 FCFA à 600000 FCFA pour planter 1 ha. La technique de production traditionnelle ne concerne que les variétés précoces que l'on récolte avant le mois de septembre ce qui favorise la formation avant la fin des pluies des semenceaux appelés généralement tête d'igname. Avec une telle pratique, les besoins en semenceaux ne sont pas couverts. Les méthodes traditionnelles de production de semenceaux d'igname présentent plusieurs inconvénients. Tout d'abord, les fragments utilisés sont grands, ce qui implique la plantation d'une quantité relativement importante de matériel végétal. Ensuite comme ces fragments sont plantés directement au champ, leur germination est le plus souvent inégale. La période nécessaire à la germination (environ 4 semaines) ne fait que prolonger la campagne. Finalement, la germination inégale et la prolongation de la campagne intensifient les besoins de sarclage (Otoo et al., 1987). En outre, dans le système traditionnel, les précautions ne sont pas toujours prises pour un bon choix de semenceaux à partir des plants sains. Une telle pratique conditionne une accumulation progressive des maladies dans le matériel végétal aboutissant malheureusement à de chutes sensibles de rendement (Dossou et al., 2000).

La production des semenceaux d'igname devient ainsi donc un élément dans la réhabilitation de cette culture. L'Institut national de recherche sur les plantes à racines et tubercules (Nrcr) d'Umudike, et l'Institut international d'agriculture tropicale (Iita) d'Ibadan collaborent depuis longtemps dans le domaine de l'amélioration de l'igname. Ces dernières années, les deux instituts ont concentré leurs efforts de recherche sur le perfectionnement d'une technique, appelée "technique de minifragments". La technique des minifragments d'igname permet la production de semenceaux de qualité si l'on sélectionne d'excellents semenceaux mères ainsi qu'un site adéquat pour la culture. Comme cette technique n'engendre pas de frais trop élevés, elle permet d'accroître le matériel de plantation et, en même temps, de stimuler efficacement la production d'igname. La motivation pour cette étude réside dans le fait que la technique est peu connue en milieu réel dans la région centrale du Bénin et peu d'études abordent les aspects économiques et organisationnels du système.

Objectifs de la recherche

- Identifier le mode de pré-germination approprié pour la technique de mini-fragmentation.
- Evaluer les aptitudes agronomiques et économiques des variétés d'igname à la technique de minifragments.
- Proposer des approches organisationnelles pour la promotion de la filière des semenceaux d'igname

Matériels et méthodes

Zones agro-écologiques. La région des Collines faisant l'objet de l'étude est caractérisée par une différenciation liée à la durée des occupations humaines et à la pression foncière: une zone de colonisation ou d'occupation ancienne (Dassa-Zoumé,

Glazoué), et une zone d'occupation relativement récente (Ouessè) à pression démographique relativement faible. La densité de peuplement et les mouvements migratoires saisonniers ou permanents ont une incidence prononcée sur l'état des ressources naturelles (sols, arbres, eaux, faune). Les activités des populations locales et les modes de prélèvement sur le stock des ressources ont entraîné durant ces dernières années des problèmes de dégradation qui fragilisent le milieu humain et naturel. Quatre sites ont été retenus dans le cadre de cette étude : Miniffi (occupation ancienne), Gomè (dominance bas-fonds), Gbanlin (occupation récente par des Mahi) et Akpéro (occupation relativement récente par des Nagot). La zone jouit d'un climat de type soudano-guinéen. Elle constitue une zone de transition entre le sud à régime pluviométrique bimodal et le nord à régime pluviométrique monomodal. La pluviométrie moyenne annuelle est de 1200 mm avec une tendance à la baisse ces dernières années. Les sols sont principalement des ferrugineux tropicaux relativement riches en éléments minéraux. Les propriétés physiques des sols sont variables selon leur teneur en argile (Agossou *et al.*, 2002). La végétation est de type savane arborée dégradée. Le maïs, l'arachide, le manioc, l'igname constituent les principales cultures vivrières. Le coton et l'anacardier constituent les principales cultures de rente. L'agriculture y est fortement marquée par des problèmes de dégradation des ressources naturelles (Dugué *et al.*, 2000).

Formation et visite d'échange des producteurs. Une formation théorique et pratique a été donnée aux producteurs et productrices d'ignames sur la technique de minifragmentation sur les sites de la recherche développement. Une visite des producteurs sur la station d'Ina dans le Septentrion du Bénin a été également organisée pour affiner davantage leur connaissance en technique de multiplication rapide des semenceaux d'igname.

Expérimentation sur la technique de minifragmentation. Un essai en milieu paysan sous gestion paysans a été conduit dans ce cadre sur les sites de Miniffi, Gomé et Gbanlin et Akpéro. Trois (03) variétés Gangni, Yanabo (variétés précoces) et Kokoro (variété tardive) appartenant au complexe des Discorea-cayeninsis rotundata ont été utilisées. Deux substrats ont été exploités: la terre sablonneuse et la sciure de bois. Au niveau de chaque site, les étapes suivantes ont été franchies pour la production des semenceaux à partir des minifragments. Préparation des minifragments (morcellement de semenceaux mères);

- Traitement des minifragments à l'aide de la cendre de bois et séchage doux;
- Pré-germination des minifragments en paniers (à Miniffi, Gomé et Gbanlin) ou à même le sol (à Akpéro). Repiquage ou transplantation des fragments. Cela a été fait en champs paysans (système traditionnel de culture continue dans les anciennes défriches) avec 15 producteurs expérimentateurs.

Le système traditionnel de production des semenceaux d'igname a été réalisé aussi bien dans les nouvelles défriches (système de défriche brûlis) que dans les anciennes défriches (système traditionnel de culture continue).

Evaluation agronomique. L'évaluation agronomique a consisté à déterminer les paramètres suivants: Taux de germination (%), Taux de levée (%), Rendement ($t\ ha^{-1}$) de matière sèche

Evaluation économique du système de production améliorée des semenceaux d'igname à partir des minifragments. Coûts des systèmes améliorés de production des semenceaux d'igname

Les coûts suivants ont été considérés dans le cadre de l'évaluation sur la base des prix pratiqués :

- Prix d'achat d'un kg de matière sèche de semenceaux *Gangni* ou Yanabo est de 150 FCFA
- Préparation des mini fragments et la mise en pépinière : 500 FCFA pour 184 mini fragments (variété *Gangni*).
- Nettoyage de la parcelle 15000 FCFA ha^{-1} .
- Buttage 32500 FCFA ha^{-1} (5 FCFA par butte).
- Transplantation des semenceaux : 2,5 FCFA par butte.
- Entretien (sarclage): 12000 FCFA ha^{-1} .
- Récolte des semenceaux d'igname : 10000 FCFA ha^{-1} (2,5 FCFA par butte).

Le taux d'actualisation (i) retenu est 3,5 % imputable aux charges variables.

L'évaluation économique a consisté à la détermination des paramètres suivants :

Produit brut, coût, bénéfice net actualisé et ratio bénéfice/coût.

Résultats et discussions

La germination des minifragments en paniers. Les taux de germinations observés sont faibles. Les taux relativement élevés ont été enregistrés pour les variétés *Kokoro* et *Gangni* avec 42 % et 35 % respectivement sur substrats sciure de bois et terre sablonneuse. Aucun effet substrat sur la germination des minifragments n'a été observé. Les faibles taux enregistrés sont liés au retard accusé pour la transplantation couplé à un excès d'eau lié aux arrosages. En effet, les pluies se sont installées tardivement au début de la campagne agricole 2002 avec une mauvaise répartition durant la grande saison sur tous les sites de recherche développement. Ainsi, à cause de ce retard des pluies, les semenceaux ayant germé dans les paniers n'ont pas été transplantés à temps aux champs où les sols étaient trop secs. Par ailleurs, les producteurs ont réalisé dans les paniers 4 à 5 strates de substrats dans les paniers. Le retard occasionné pour la transplantation et

l'arrosage répété ont entraîné beaucoup de pourriture surtout dans les strates inférieures des paniers. Les taux de germination étaient nuls dans les trois dernières strates des paniers.

La germination des minifragments à même le sol. Dans le Tableau 4 sont consignés les résultats des taux de germination des minifragments installés à même le sol en plein champ ou sur une berge (proche d'un cours

Tableau 1: Structure des coûts investis (FCFA/400m²) pour la production des semenceaux d'igname dans les systèmes d'anciennes et nouvelles défriches.

Désignation	Variétés d'igname					
	Gangni		Kokoro		Yanabo	
	Tr	Ta	Tr	Ta	Tr	Ta
Densité des buttes sur 400 m ²	207	400	211	500	133	340
Défrichement de la parcelle	200	200	200	200	200	200
Incinération des arbres	100	100	100	100	100	100
Buttage	600	1000	500	1250	300	850
Achat de semenceaux	6500	8000	3500	5000	5000	7000
Plantation des semenceaux	350	500	250	625	150	425
Sarclage 1 de la parcelle	400	400	400	400	400	400
Sarclage 2 de la parcelle	400	400	400	400	400	400
Récolte des prémices	300	500	250	625	150	350
Récolte des semenceaux	350	500	250	625	150	350
Coût imputable aux charges variables	350	406	205	323	240	350
Coût total	9550	12000	6055	9550	7100	10450

Tr : système traditionnel de production d'ignames dans les anciennes défriches (système de culture *continue*).

Ta : système traditionnel de production d'ignames dans les nouvelles défriches (système de défriche-brûlis).

Tableau 2: Structure des coûts investis (FCFA/400m²) pour la production améliorée des semenceaux d'igname.

Opérations	Variétés d'ignames		
	Gangni	Kokoro	Yanabo
Achat de tubercules-mères (ex. 24 kg pour <i>Gangni</i>)	3500	1000	1050
Préparation et mise en pépinière (ex.184 minifragments pour <i>Gangni</i>)	500	175	180
Nettoyage de la parcelle	500	175	180
Buttage de la parcelle	1100	350	360
Transplantation des mini fragments	400	100	120
Entretien 1 de la parcelle	400	100	120
Entretien 2 de la parcelle	400	100	120
Récolte des semenceaux d'igname	500	150	150
Coût imputable aux charges variables	260	75	80
Coût total	7560	2225	2360

d'eau) sous abri dans la zone d'Akpéro avec les deux substrats (terre sablonneuse et sciure de bois). Les taux de germination observés sont relativement élevés (47% à 60%) quel que soit le substrat. Les cas de pourriture observés étaient dus au retard de transplantation et à l'excès d'eau lié aux arrosages. Cependant un faible taux de germination (10%) a été enregistré en plein champ avec la variété *Gangni* sous substrat sciure de bois lié à un manque d'eau.

Il ressort des résultats des Tableau 3 et 4 que le mode de pré-germination à même le sol

sous abri (arbres) apparaît plus indiqué pour la technique de minifragmentation des semenceaux.

Production des semenceaux en champs paysans.

La production des semenceaux à Miniffi était relativement élevée pour la variété *Gangni* 3,11t ha⁻¹ suivie de celle de *Kokoro* 0,82 t ha⁻¹ (Tableau 5). La différence de rendement entre ces deux variétés testées est significative au seuil de 5%. Ceci est lié à une bonne levée pour la variété *Gangni* (64,5%) par rapport aux autres variétés (38% et 18 %)

Tableau 3: Situation des minifragments disposés en paniers sous abris pendant la phase de pré-germination à Miniffi, Gomé et Gbanlin (2002).

Site	Variété	Substrat	Nombre de minifragments en pépinière	Nombre de minifragments germés	Taux de germination (%)
Miniffi	Gangni	Terre sablonneuse	-	-	-
Gomé			255	90	35
Gbanlin			1000	101	10
Miniffi	Kokoro	Sciure de bois	900	53	6
Gomé			277	115	42
Gbanlin			1000	99	10
Miniffi	Yanabo	Sciure de bois	608	8	1
Gomé			455	42	9
Gbanlin			-	-	-
Total			4495	508	11

Le Tableau 3 indique les résultats de la technique de minifragmentation réalisée sur les sites de Miniffi (Dassa-Zoumè), Gomé (Glazoué) et Gbanlin (Ouessè) dans des paniers pourvus de deux substrats (terre sablonneuse et sciure de bois).

Tableau 4: Situation des minifragments disposés au sol sous abris pendant la phase de pré-germination à Akpéro (2002).

Site	Variété	Substrat	Nombre de minifragments en pépinière	Nombre de minifragments germés	Taux de germination (%)
Akpéro	Gangni	Terre sablonneuse	191	90	47
		Sciure de bois	401	40	10
	Kokoro	Terre sablonneuse	337	196	58
		Sciure de bois	340	205	60
	Yanabo	Terre sablonneuse	99	55	56
		Sciure de bois	530	248	47
Total			1898	834	44

respectivement pour *Kokoro* et *Yanabo*. Pour le cas particulier de la variété *Yananbo*, des pourritures ont été observées à la récolte à Miniffi liées à un état de sécheresse. Pour les autres paramètres de rendement, *Kokoro* montraient 1 à 2 tubercules par plants par rapport à *Gangni* (un tubercule par plant) avec une différence significative au seuil de 5%. En outre, le poids moyen d'un tubercule était de 230 g pour *Gangni* et 4 g pour *Kokoro*. La variété *Gangni* présente une bonne aptitude agronomique à la technique de minifragmentation par rapport à *Kokoro* et *Yanabo* sur le site de Miniffi.

La variété *Gangni* affichait sur le site de Akpéro (site moins dégradé) une production de 9,45 t ha⁻¹ contre 5,58 t ha⁻¹ et 4 t ha⁻¹ respectivement pour *Kokoro* et *Yanabo* (Tableau 6). La différence de rendement n'était pas significative entre ces trois variétés testées. Une bonne levée des plants a été observée également pour les trois variétés (80%; 52% et 66%) respectivement pour *Gangni*, *Kokoro* et *Yanabo*. Pour les autres paramètres de rendement, *Gangni* montrait 1 à 2 tubercules par plants par rapport à *Kokoro* et *Yanabo* (1 à 3 tubercules par plant). Les tubercules de *Gangni* à la récolte étaient

Tableau 5: Rendements et composantes de rendement des différentes variétés testées à Miniffi (Dassa-Zoumè).

Variété	Rendement (t ha ⁻¹) de matière fraîche	Taux de levée(%)	Nombre de tubercules par plant	Poids moyen d'un tubercule (kg)	Poids des tubercules par plant
Gangni	3,11	64,5	1,17	0,23	0,26
Kokoro	0,82	38	1,59	0,04	0,05
Yanabo	0,0	18	0,0	0,0	0,0
Moyenne	1,31	40,1	0,92	0,09	0,1
Ppds (5%)	1,64	NS	0,7	0,19	0,22
CV (%)	49,96	61,93	30,28	86,94	82,39
Ecart type	0,65	24,88	0,28	0,08	0,09
Probabilité F	0,00334	0,3125	0,00143	0,02353	0,02372

Ppds (5%) : Plus petite différence significative à 5%; CV(%) : Coefficient de variation ;NS : Non significatif au seuil de 5%.

Tableau 6: Rendements et composantes de rendement des différentes variétés testées à Akpéro (Ouessè).

Variété	Rendement (t ha ⁻¹) de matière fraîche	Taux de levée(%)	Nombre de tubercules par plant	Poids moyen d'un tubercule (Kg)	Poids des tubercules par plant (kg)
Gangni	9,45	80,45	1,39	0,27	0,38
Kokoro	5,58	51,68	2,68	0,06	0,15
Yanabo	4	65,74	2,46	0,12	0,27
Moyenne	6,34	65,96	2,18	0,15	0,27
Ppds (5%)	NS	NS	NS	NS	NS
CV (%)	58,89	17,44	37,99	42,35	43,20
Ecart type	3,73	11,5	0,83	0,06	0,12
Probabilité F	0,43167	0,18457	0,37139	0,0901	0,2974

Ppds (5%) : Plus petite différence significative à 5%; CV(%) : Coefficient de variation; NS : Non significative au seuil de 5%.

relativement plus gros avec un poids moyen de 270 g contre 7g et 120 g respectivement pour *Kokoro* et *Yanabo*.

Les rendements n'ont pas pu être évalués sur les sites de Gomé et Gbanlin dus à des pertes de culture liées respectivement à l'engorgement des sols des bas-fonds et à un mauvais entretien des parcelles de culture.

Comparaison des rendements et composantes des rendements selon les niveaux de fertilité des sols. La Figure 1 montre le taux de levée des minissets à Akpéro et Miniffi.

A Akpéro (zone à faible pression sur la terre donc moins dégradée), les variétés précoces *Gangni* et *Yanabo* présentaient par rapport à Miniffi (zone à pression foncière relativement élevée donc plus dégradée), une bonne levée quatre semaines après transplantation par rapport à *Kokoro* (variété tardive) La production de tubercules (Figure 2) était relativement élevée à Akpéro qu'à Miniffi liée à une fertilité plus élevée des sols à Akpéro.

Le nombre de tubercules par plant semble plus élevé pour les variétés *Kokoro* et *Yanabo* à Akpéro qu'à Miniffi (Figure 3). L'état de

fertilité initial des sols semble influencer sur le nombre de tubercules par plant.

La variété *Gangni* présente une bonne aptitude agronomique à la technique de minifragmentation par rapport à *Kokoro* et *Yanabo* sur les deux sites.

Il ressort des résultats des Figures 3 à 5 que les rendements et les composantes de rendements des tubercules étaient relativement élevés à Akpéro liés à une fertilité plus élevée des sols. Il existe, en effet, une différence de fertilité entre Miniffi (zone à forte pression foncière) et Akpéro (zone à pression foncière relativement faible), Agossou et *al.*, 2002. La production des tubercules d'igname est donc corrélée à l'état de fertilité initial des sols.

Toutefois, les résultats sur le taux de germination, les rendements et les composantes de rendement des différentes variétés testées dans la région des collines étaient faibles par rapport à ceux observés en station dans le Département du Borgou (au Nord du Bénin) au cours des années antérieures. Cet état de chose est dû aux conditions de réalisation de l'essai. En effet, dans le cadre de cet essai, la pré-germination des semenceaux d'igname a été réalisée tardivement (mai- juin) et la transplantation

Advances in yam (*Dioscorea* spp.) genetics and genomics

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Abstract. Yams (*Dioscorea* spp.) constitute a staple food crop for over 100 million people in the humid and subhumid tropics. They constitute a multi-species, polyploid crop that is vegetatively propagated. *Dioscorea rotundata* and *D. cayenensis* (known as white and yellow Guinea yams, respectively) are the most important yams in West and Central Africa where they are indigenous, while *D. alata* (referred to as water yam) is the most widely distributed species globally. The genetics of yams is least understood among the major staple food crops due to several biological constraints and research neglect. Research to unravel the apparent complexity of the yam genome will have far-reaching implications for genetic improvement of this important tuber crop. Some progress has been made in recent years in germplasm characterization and the development of molecular markers for genome analysis. Genetic linkage maps based on amplified fragment length polymorphism (AFLP) markers have been constructed for *D. rotundata* and *D. alata*. These linkage maps were used to scan the genome for quantitative trait loci (QTL) associated with genes conferring resistance to *Yam Mosaic Virus* (YMV) in *D. rotundata* and anthracnose (*Colletotrichum gloeosporioides*) in *D. alata*. In addition, candidate random amplified polymorphic DNA (RAPD) markers associated with major genes controlling resistance to YMV and anthracnose have been identified that could be used for selection and pyramiding of YMV and anthracnose

resistance genes in yam improvement. Also, molecular markers such as RAPDs, AFLPs, and microsatellites or simple sequence repeats (SSRs) have been developed for yam genome analysis. An initial c-DNA library has been constructed in order to develop expressed sequence tags (ESTs) for gene discovery and sources of additional molecular markers. This paper will review the advances made, discuss the implications for yam genetic improvement and germplasm conservation, and outline the direction for future research.

Introduction

Yam (*Dioscorea* spp) is a multi-species, polyploid and vegetatively propagated tuber crop that is cultivated widely in the tropics and subtropics. Over 90% of world yam production occurs in the yam belt of West and Central Africa with Nigeria alone accounting for about 68 percent of the world's total (FAO, 2002). Yam production has increased steadily in the last decade, from 18 million metric tonnes in 1990 to recent estimates of over 39 million (FAO, 2002). This increase has been achieved mainly through the use of traditional landraces and can be explained by the rapid expansion in acreage of yam fields into marginal lands and in non-traditional yam growing areas. Yam yields peaked during the drought year of 1992, and there is need to provide farmers with improved varieties that combine high yields with pest and disease resistance, and acceptable tuber quality.

Of the 600 known species of yams, only six are edible or food yams. *Dioscorea rotundata* and *D. cayenensis* (known as white and yellow Guinea yams, respectively) are the most popular and economically important yams in West and Central Africa where they are indigenous, while *D. alata* (referred to as water or greater yam) is the most widely distributed species globally. Guinea yams were domesticated in West Africa, while water yam is believed to be a true cultigen that might have been domesticated in Indo-China from *D. hamiltoni* and *D. persimilis* (Barrau, 1965). In West and Central Africa where Guinea yams were domesticated about 7000 years ago, farmers have selected genotypes that best fit their needs, and thus, have generated a large number of traditional cultivars.

Genetic improvement programmes at IITA (Nigeria) and at the Central Tuber Crops Research Institute (CTCRI, India) have been developing high yielding *D. alata* and *D. rotundata* varieties with pest and disease resistance to meet farmers' requirements. To achieve breeding goals, these institutions and other yam improvement programmes in different countries have collected and maintained more than 3,000 germplasm accessions that are being used for yam improvement. There is tremendous genetic variability in yam. Contrary to the situation in other crops where the deployment of improved varieties has led to loss of diversity and a narrowing of the genetic base, some kind of domestication of semi-wild yam species is still on going in west African countries, which continually augments the germplasm diversity (Mignouna and Dansi, 2003). Among the wild yam species most often used for domestication (*D. abyssinica* Hochst. ex Kunth, *D. praehensilis* Benth and *D. burkilliana* J. Miegé), *D. praehensilis* is the most important and most exploited in Benin Republic.

Through classical breeding several clones and populations of white and water yams have been developed by IITA in partnership with national programmes in Africa and disseminated for further evaluation and selection under local environmental

conditions. Through collaborative evaluation of IITA breeding lines with the National Root Crop Research Institute (NRCRI, Umuahia, Nigeria), three varieties of white yam were officially released in Nigeria in 2001 and four in 2003. More lines are in the pipeline to be released by the root crop programme in Nigeria and other yam producing countries like Benin, Burkina-Faso, Cote d'Ivoire, Ghana, Sierra Leone, and Togo. These varieties have multiple pest and disease resistance, wide adaptability and good organoleptic attributes. Progress in breeding for increased yield, adaptability to marginal environments, improved tuber quality, and pest and disease resistance has, however, been painfully slow due to biological constraints that impede the elucidation of the genetics of important traits in yam. These include a long growth cycle, dioecy, poor to non-flowering, polyploidy, vegetative propagation, a heterozygous genetic background and poor knowledge of the organization of crop diversity.

The long growth cycle of yam, lasting about 8 months or more, exposes the crop to a plethora of pests and diseases among which anthracnose (*C. gloeosporioides*) and Yam Mosaic Virus disease can be particularly damaging (Thouvenel and Dumont, 1990; Green, 1998). The long period to harvest hinders the flexibility of availability, an important trait for any industrial crop, and considerably lengthens the gestation period for new improved varieties. The vegetatively propagated nature of the crop means that securing clean and healthy planting materials can be an ordeal for poor farmers. Yam is cultivated in widely varying agroecological zones. In Nigeria, for instance, the crop is grown from the southern humid forest to the northern Guinea savanna. Performance of genotypes is very disparate across regions, thereby multiplying breeding goals.

The advent of molecular markers, genome studies, and plant genetic transformation has opened avenues for circumventing breeding obstacles in long growth cycle and heterozygous crops like yam. In spite of these opportunities to build on the success in

classical breeding, huge challenges had to be overcome before yam scientists could develop modern technologies towards assisting breeding programmes to boost yam production and keep up with the ever-increasing demand. To address these challenges, breeding efforts were revived at IITA in early 1990s, along with a project to develop molecular techniques to unravel the yam genome. This blending of traditional and biotechnological approaches was initiated with funds provided by the Gatsby Charitable Foundation, UK and involved IITA, John Innes Centre, and the Natural Resources Institute, UK.

A better understanding of available genetic diversity and the breeding potential of specific accessions is important for the choice of parents for use in breeding programmes. First, IITA began by developing molecular markers for genetic resource characterization and genetic diversity studies. Yams are polyploid, male and female plants are separate, and both are needed to obtain true botanic seeds. In addition, flowering of male and female plants is difficult to synchronize. The early testing of progenies from hybridization was complicated by yam's slow multiplication rate and the juvenile phase during which it is unreliable to use conventional screens for some economic traits. Molecular markers that are linked to genes controlling these economic traits would be useful in selection at an early stage of the plant's growth, thereby enhancing the speed and efficiency of selection.

Yam genome mapping was initiated in the mid-1990s. However, the lack of mapping populations and adequate polymorphic molecular markers hampered rapid progress. By the end of 2001, considerable progress had been made in developing appropriate molecular tools and mapping populations for developing linkage maps of the two most important species, *D. alata* and *D. rotundata*. This review will cover the progress made in molecular marker development, characterization of genetic diversity, linkage mapping, QTL analysis and development of genomic resources.

Development and Evaluation of Molecular Markers. The initial effort in yam genomics was devoted to the development of polymorphic markers and assessment of their potential application in yams. Yams are monocots but very distantly related to the grasses; for example, banana and wheat are more closely related to each other than either is to yam. Thus there is no convenient model system for yam genomics. During the course of this project, several attempts were made to exploit heterologous DNA sequences as a source of RFLP markers. This approach had limited success and there was the need to isolate a set of yam gene sequences as a priority for anchoring yam genetic maps. However, the use of this type of DNA sequence for generating large data sets needed to populate genetic maps is not cost efficient, so the approach of using uncharacterised DNA sequences was adopted as a source of genetic markers. In this regard, random amplified polymorphic DNA (RAPD) and amplified fragment length polymorphic DNA (AFLP) were the molecular markers of choice (Mignouna *et al.*, 1998).

RAPD and AFLP polymorphism were high among diverse yam species, with AFLP revealing the highest polymorphism. A total of 64 AFLP primer combinations were tested for their potential use in assessment of genetic diversity in white Guinea yam (Mignouna *et al.*, 1998). Over 1000 polymorphic AFLP markers were identified using the 64-primer pairs. Although RAPD markers were adequate for genetic diversity studies, the level of polymorphism detected in mapping populations was low; RAPD was, therefore, not considered a good marker-system for mapping purposes. Contrary to RAPDs, the high level of polymorphism revealed by AFLP markers coupled with their robustness made AFLP a more reliable and reproducible marker-system both for yam genome analysis and mapping purposes. AFLP markers were not only useful for genome mapping but were also very useful for population genetic studies in yam. As progress was being made in yam genomics,

microsatellite or simple sequence repeat (SSR) markers were required. Thirty-six microsatellite primers were developed from a genomic library and tested for ability to detect polymorphism in genetic diversity studies of white Guinea yam. The major strength of microsatellites lies in their expected high polymorphism, co-dominant inheritance, high abundance and an even distribution across the genome. Because of the relatively small number of markers developed and the low level of polymorphism detected in mapping populations, microsatellites were not considered a good marker-system for mapping purposes. Additional yam microsatellite markers need to be developed.

The efficiency of AFLP, RAPD and SSR markers for the assessment of genetic relationships, as well as for identification and discrimination among 45 West and Central African white yam cultivars belonging to 22 morphotype/cultivar groups was investigated. The results showed that each of the three marker-systems could unequivocally identify each cultivar, but that marker-systems differed in the mean number of profiles generated per primer (or primer combination) per cultivar, referred to as Genotype index (GI). The order of merit based on this criterion was AFLP (GI = 1.0), SSR (GI = 0.39) and RAPD (GI = 0.35). Thus AFLP showed the highest efficiency in detecting polymorphism and revealed genetic relationships that most closely reflected morphological classification (Mignouna et al., 2003). Mignouna et al. (1998) previously showed that AFLP is a sensitive and robust technique for yam genome fingerprinting. In spite of their robustness, technical and financial burdens associated with AFLP and SSRs limit their availability to laboratories in developing countries where most of the research on yam is conducted. Thus cost considerations may make RAPD the method of choice for laboratories with rather limited resources.

Progress in molecular genetic analysis of the yam genome. The ability to use molecular marker biotechnology to exploit information

at the gene level, based on genome mapping and marker-assisted genetic analysis and breeding, now offers a practical solution to many of the intractable problems in yam breeding. Molecular genetic maps and marker-aided analysis of complex traits can be used to elucidate the genetic control of yield potential and tuber quality, and locate genes for pest and disease resistance, nutrient use efficiency, and flowering. For these reasons, a concerted effort to map the yam genome and dissect the inheritance of complex traits was initiated at IITA. The marker type chosen was AFLP, and an early goal was to make this methodology available at IITA, where the procedure has a general applicability, including germplasm characterization, genetic mapping and marker-aided selection.

Segregating populations and inheritance of disease resistance.

It was anticipated that cultivated yams would have their origin from a cross between genetically distinct individuals, so the alleles derived from each parent may be different. Similarly cultivated yams are tetraploid ($2n = 4x = 20$), so each genetic locus is expected to be represented by two homeologous pairs. Thus for any gene a given individual may have up to four alleles. One general approach to mapping plants of this type is to examine the genotypes of selfed progeny; however, this is not feasible for dioecious yams, so the approach taken was to generate multiple F_1 individuals derived from crosses between the same parents. F_1 mapping populations of *D. alata* and *D. rotundata* were subjected to in vitro micropropagation based on techniques developed by Ng (1992). *D. rotundata* populations segregated for components of resistance to *Yam Mosaic Virus*, genus *Potyvirus* (Mignouna et al., 2001b), while the *D. alata* populations segregated for yam anthracnose disease resistance (Mignouna et al., 2001a).

Yam Mosaic Virus is a major limiting factor for stable production of yams and *D. rotundata* is particularly susceptible to the virus (Thouvenel and Dumont, 1990). Genetic

resistance is the only economically viable method of control. A study of the genetic control of YMV resistance in three *D. rotundata* cultivars to a Nigerian isolate of YMV showed that resistance is manifested differentially as the action of a single dominant gene in simplex condition or a major recessive gene in duplex condition (Mignouna et al., 2001b). The dominant locus that contributes to YMV resistance was tentatively named *Ymv-1*, until tests of allelism are conducted. The availability of genotypic diversity for YMV resistance is extremely interesting to breeding programmes because both genes could be pyramided in the same genetic background or used separately against infection by this virus. Anthracnose disease, caused by *Colletotrichum gloeosporioides* (Abang et al., 2002), is a major constraint to the production of yam worldwide (Winch et al., 1984; McDonald et al., 1998), with *D. alata*, the most widely distributed species, being particularly susceptible to the disease. Resistant yam cultivars could form the basis of sustainable management strategies for anthracnose. Initial genetic inheritance studies showed that resistance to yam anthracnose in *D. alata* is dominantly but quantitatively inherited (Mignouna et al., 2001a). A single major dominant locus controlling resistance in the breeding line TDa 95/00328 was tentatively designated *Dcg-1*, until allelism is investigated. The efficiency and effectiveness of breeding for YMV and anthracnose resistance will be greatly improved by marker-assisted selection based on genetic mapping of major genes controlling the resistance.

Genetic mapping and QTL analyses.

Chromosome pairing in tetraploids can occur such that only homologues pair, or such that any two homeologues may pair. These two types of pairing have very different consequences for segregation patterns so that these plants may, in the extreme, exhibit either diploid or tetraploid genetics. Intermediate types of behaviour may also occur. Thus it was important to establish

which type of segregation was being seen in the cultivated yams. Genes controlling important traits such as yield, tuber quality, and pest and disease resistance are usually distributed among several quantitative trait loci (QTLs), which may not be linked, thus making these traits difficult to manipulate using conventional breeding methods. The recessive nature of *Yam Mosaic Virus* resistance in some *D. rotundata* genotypes means that such resistance cannot be easily tracked at the phenotypic level, demanding refined diagnostic procedures such as molecular mapping for detailed genetic localization of specific genes (Mignouna et al., 2001b). Screening by molecular markers linked to QTLs has the advantage of selecting pairs of parents with genes at different QTLs for the same trait (Solomon-Blackburn and Barker, 2001). Using traditional cultivars/landraces and breeding lines, researchers initiated experiments to identify quantitative trait loci (QTL) affecting these traits.

A preliminary study on genetic mapping of *D. rotundata* also revealed diploid segregation patterns for alleles at RAPD, isozyme and a few AFLP marker loci (Mignouna and Asiedu, 1999). In that study, the detection and estimation of linkage was carried out according to the pseudo test cross method using single dose markers (SDM) because the genome constitution of yam was not known (allo-versus auto-polyploid). This approach resulted in a rather limited linkage map comprising 4 linkage groups made of 12 markers each for the male and female parents (Mignouna and Asiedu 1999), mainly because only a small proportion of RAPD and AFLP markers that were polymorphic between the two parents fit the condition of SDM. This situation explains the use of a more polymorphic source of markers such as AFLP.

Genetic mapping using AFLP led to the construction of the first, separate, comprehensive, molecular linkage maps of *D. rotundata* and *D. alata*. The largest single map contains 341 co-dominantly scored AFLP markers segregating in an intraspecific F_1 cross. The mapping population was produced

by crossing a landrace TDr 93-1 as female parent and a breeder's line TDr 87/00211 as the male parent. The markers segregated like a diploid cross- pollinator population suggesting that *D. rotundata* genome is an allo-tetraploid ($2n = 4x = 40$). However, the possibility that occasional homeologous exchanges may occur cannot be ruled out. Three QTLs with effect on resistance to YMV were identified on the maternal linkage map, while one QTL for YMV resistance was detected on the paternal linkage map (Mignouna et al., 2002d). These results showed that both parents contributed to the phenotypic resistance of the progeny.

Similarly, a genetic linkage map of the tetraploid water yam (*Dioscorea alata*) genome was constructed based on 469 co-dominantly scored AFLP markers segregating in an intraspecific F_1 cross. The F_1 was obtained by crossing two improved breeding lines, TDa 95/00328 as female parent and TDa 87/01091 as the male parent. The 469 markers were mapped on 20 linkage groups with a total map length of 1,233 cM. Again, the markers segregated as in a diploid cross-pollinator population, suggesting that the water yam genome is allo-tetraploid ($2n = 4x = 40$). One QTL located on linkage group 2 was found to be associated with anthracnose resistance, explaining 10% of the total phenotypic variance (Mignouna et al., 2002c). Conservative estimates put the genome coverage of the *D. rotundata* and *D. alata* maps at 45% and 65%, respectively. There are several reasons why the maps may not give complete coverage. The most obvious is that the two parents may have some common ancestry so that segments of the linkage maps may be devoid of polymorphism and thus cannot be identified in genetic analysis.

One approach to trying to gain some insight on this issue would be to attempt to align the *D. alata* and *D. rotundata* maps. This would give us additional confidence in the general map structures and enable the development of suitable markers for genomic surveys of other populations. One attempt was made to derive gene sequence based

markers, but unfortunately the cDNA library used for this analysis contained an unexpectedly high proportion of rRNA sequences. Nevertheless this remains a sensible objective, and would also permit the alignment of these maps with that recently presented for *D. tokoro* (Terauchi and Kahl, 1999). Both maps provide useful tools for further genetic analysis of agronomically important traits in yam. While AFLPs continue to be identified and used for mapping the yam genome, efforts are geared towards saturating the map with microsatellites (SSRs) and ESTs, for greater ease of application in yam breeding.

Identification of candidate genes. Selective genotyping is a very effective approach for initial QTL analysis in plants (Van Gestel et al., 2000). Because of the large families that can be generated for genetic analysis and the clonal status of each genotype of the segregating population, selective pressure can be applied in phenotypic evaluations following which, extremes of phenotype are selected for genotyping. For example, selective genotyping coupled with DNA sample pooling has been shown to be very efficient for initial identification of markers linked to genes for disease resistance. The approach has been successfully applied in yams for identification of YMV and anthracnose resistance genes (Mignouna et al., 2002 a, b). Two RAPD markers OPW18₈₅₀ and OPX15₈₅₀ closely linked in coupling phase with the dominant YMV-resistance locus *Ymv-1* were identified. These markers successfully identified the resistance gene in resistant genotypes among a sample of 12 *D. rotundata* varieties. Similarly, a single locus, *Dcg-1*, that contributes to anthracnose resistance was identified in *D. alata*. Two RAPD markers, OPI17₁₇₀₀ and OPE6₉₅₀, closely linked in coupling phase with *Dcg-1* were identified. Both markers successfully identified *Dcg-1* in resistant *D. alata* genotypes among 34 breeding lines, indicating their potential use in marker- assisted selection. The RAPD markers identified in these studies will be

made more reliable, specific and easier to apply for indirect selection by converting them into co-dominant PCR-based sequence characterised amplified regions (SCARs). Further AFLP mapping is planned to identify additional QTLs and strengthen existing marker-QTL linkages. Candidate gene analyses are yet to be employed to investigate a variety of traits. To date, significant associations have been demonstrated for disease resistance in many crops, such as tomato and potato. The Yam breeding programmes at IITA is initiating the use of MAS for selecting parental lines for breeding purposes. It is likely that as QTL experiments are expanded, additional genes will be identified for use in breeding.

Initial QTL studies indicated that the pyramiding of major resistance genes may be a valuable strategy for YMV and anthracnose resistance breeding (Mignouna et al., 2002a, b). This strategy is appropriate if the pathogen is exclusively asexual/clonal and if the potential for gene flow is low. But if the pathogen is recombining then the recombination of virulence alleles may occur as quickly as breeders can recombine resistance genes, thus frustrating breeding efforts (McDonald and Linde, 2002). This appears to be the case with *C. gloeosporioides* whose sexual stage *Glomerella cingulata* is present in yam fields (Abang, 2003), and field populations have been shown to exhibit extremely high genotypic diversity (Thottappilly et al., 1999; Abang, 2003). If the sexual stage plays an important role in yam anthracnose epidemics, then yam breeders will have to consider laying emphasis on race non-specific resistance and increased diversity in host populations (McDonald and Linde, 2002).

Current Developments and Associated Bottlenecks in Yam Genome Analysis

Development of genomic resources. The development of genomic resources and technology is a major focus in the yam genetics and breeding community. To date,

one genomic DNA library has been developed (unpublished data). A cDNA library has been made from male flowers. The cDNA library was made in Bluescript vector. This cDNA library was used for EST analysis because this approach has been proven to be the most efficient for gene identification, gene expression profiling and cataloguing. It also provides markers and resources for the development of cDNA microarrays. In yams, 1100 ESTs have been sequenced and most genes are ribosomal protein genes. Microarrays are not yet available for yams, mainly because the number of available genes is still very small.

Another reliable and potentially powerful way of identifying candidate loci controlling agronomic traits in yam is by the application of the cDNA/AFLP technique, which generates polymorphic transcript derived fragments (TDFs) between the parents of a mapping cross. Once candidate genes have been identified, they can be employed in gene tagging and QTL mapping studies to look for associations between the candidate gene and the trait in question. The availability of a BAC library and the development of an effective system for transforming yam with large DNA fragments will provide conclusive evidence of the contribution of the candidate gene, through complementation studies.

Development of ESTs from cDNA. The genome size of tetraploid *D. rotundata* was estimated by Feulgen-stained root tip nuclei to be 0.8 pg per haploid nucleus, and thus is equivalent to the genome size of species such as rice, soybean and spinach (Conlan et al., 1995). The current yam map covered a minimum of 56 % of the yam genome. Considering the haploid nuclear DNA content of *D. rotundata* to be 800Mbp/IC the physical distance per map unit could be estimated at 4000 kb per cM, making map based cloning feasible. So far research data suggest that the yam genome is an allo-tetraploid $2n=4x=40$. As with other species, we have generated ESTs from cDNA clones randomly picked from libraries constructed from male and female

flowers. This project, sponsored by Gatsby Charitable Foundation, has led to the sequencing and initial analysis of 1,100 ESTs. Unfortunately, most of the sequenced ESTs were either ribosomal or housekeeping genes. It will be useful to pursue this initiative in order to generate more useful genes for genomic studies. The data obtained by sequencing additional ESTs will be helpful in comparative mapping efforts with other root and tuber crops, candidate gene discovery, and gene expression analysis.

Development of microarray system for functional analysis. To understand the physiological complexity of the yam genome, expression and/or functional gene analyses need to be undertaken. Northern analysis and differential display PCR techniques can be used, but these techniques have limitations as to the number of genes that can be analyzed simultaneously. There is a need to develop/consider approaches such as the use of cDNA on microarrays. Other plant microarrays could be tested and used. However, as pointed out earlier, the development of a large number of ESTs will allow larger scale expression analyses.

Future Perspectives

With the development of new genotypes of yam through hybridization by IITA scientists, new materials are being made available both in seed and clonal form (through tissue culture) to a number of African countries. Requests have been received from Rwanda, Guinea Conakry, Gambia, Guinea Bissau, Kenya, Equatorial Guinea, as well as from Cuba, Japan and Colombia. Other countries that have shown interest include Sudan, Uganda, and Malawi. It is hoped that in the near future yam cultivation will expand and become popular in other African countries, particularly in East and Central Africa. Molecular markers should make yam breeding more efficient, and thus reduce the cost and time required to produce new varieties.

Understanding and exploiting the complexity of the yam genome for improved yield and quality of yams remains a huge challenge. Large-scale gene identification and mapping have taken place in a number of model plants (e.g. *Arabidopsis* and *Medicago*) as well as some important food crops (e.g. rice, soybean, tomato and maize). Whole genome sequencing and expression analyses have been conducted in *Arabidopsis* and rice, and offer opportunities to understand the biological complexity of other plant genomes. However, these advances are yet to benefit under-researched food crops such as yams.

Efforts in yam genetics and genomics should be pursued and we believe the following specific areas need to be addressed in the near future. First, genetic linkage mapping of both species should be continued. A consensus and denser genetic map for both species must be constructed for practical breeding and germplasm enhancement purposes. QTL mapping should be reactivated with the initial identification of markers linked to disease resistance genes; more QTL markers should be sought. Candidate gene identification using microarray and other approaches should be conducted in order to pin down the genes (QTLs) involved in important agronomic traits. BAC library construction should be initiated, and efforts towards establishing a system for yam transformation should now be given more impetus (Tor et al., 1998). Embryo rescue will enable yam breeders to successfully make wide crosses with a greater number of related species of wild yams and have access to a much wider range of genes that can be used for the genetic improvement of yams. Wide crosses and embryo culture hold great promise for the transfer of tolerance to biotic and non-biotic stresses from wild relatives to cultivated yams. Research to better understand the biology and agronomy of wild relatives will greatly facilitate efforts aimed at unlocking the genetic potential hidden in the wild yam germplasm.

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Characteristics and control of a new basidiomycetous root rot of cassava (*Manihot esculenta*) in Ghana

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Abstract. Cassava (*Manihot esculenta*) is one of the most important food crops in the tropical world. Diseases such as African cassava mosaic virus (ACMV), cassava bacterial blight (CBB) and cassava anthracnose (CAD) constitute a major constraint to cassava production in parts of sub-saharan Africa. A mushroom type of fungus previously known to be parasitic on forest tree species has in recent years been found attacking cassava and causing high yield losses in some of the major cassava growing districts in Ghana. Surveys have established presence of the disease in the Volta, Central and Ashanti regions of the country. Major symptoms of the disease include wilting and defoliation and eventually plant death. Storage roots of infected cassava plants are often rotten and result in yield losses as high as 100%. Local and improved genotypes of cassava available to farmers in endemic areas are susceptible to attacks by this fungus. The large, bright yellow fruiting body produced by the fungus is characteristic of the basidiomycete *Polyporus sulphureus* (*Laetiporus sulphureus*). Citrus and a number of important timber tree species are also hosts of this fungus. Results from field screening of cassava genotypes indicate that materials with high levels of resistance to this fungus are available.

Introduction

Cassava (*Manihot esculenta*) is one of the most important food crops in the tropical world and the principal carbohydrate source for more

than 500 million people in the developing world (Lozano, 1986; Farquet and Fargette, 1990; Thresh *et al.*, 1997). Diseases such as African cassava mosaic virus (ACMV), cassava bacterial blight (CBB) and cassava anthracnose (CAD) constitute a major constraint to cassava production in parts of sub-saharan Africa where the crop is cultivated. ACMV alone potentially causes yield losses of about 50% in susceptible cultivars (Farquet and Fargette, 1990; Lozano and Nolt, 1989). Farmers in most parts of Africa do very little or practically nothing to control diseases of cassava and are often satisfied with the reduced yields they obtain from susceptible varieties they cultivate (Thresh *et al.*, 1994).

In addition to the major diseases (ACMV, CBB and CAD) cassava is also affected by root rot infections. Root rot diseases of cassava are common in poorly drained soils especially in periods of excessive rainfall or when cassava is planted in areas where forest trees previously grew. Rots of cassava in poorly drained soils could be due to *Phytophthora* species (Cook, 1978). Soft rots caused by *Phytophthora* spp. are characterized by exudation of liquids with foul smell often from swollen storage roots (Lozana and Sequira, 1974; Oliveros *et al.*, 1974). This rot is prevalent in waterlogged soils. *Botryodiplodia throbromae* has been isolated frequently from rotten cassava roots harvested from poorly drained soils in Ghana. Control of these rots lie in avoiding poorly drained soils.

In the last decade however, few new diseases of cassava have been identified in Ghana. One of these new diseases is caused by a basidiomycete previously known to be a fungal parasite of woody forest tree species. In the last decade this new parasite of cassava has been observed to be causing significant yield losses in important cassava growing districts of the country. The basidiomycete produces a bright yellow fruiting body which is characteristic of *Polyporus sulphureus* (*Laetiporus sulphureus*). The parasite which was first observed in one of the ten regions of the country in the early 1990s but is now present in five important cassava growing regions of southern Ghana. Severe yield losses ranging between 50 and 100% have been recorded in disease hot spot areas of Central and Volta regions of the country (Moses 2001). Symptoms of the disease include wilting, defoliation and root rot as observed in most root rot diseases of cassava (Msikita *et al.*, 2000). In areas where this root rot disease has been reported, it is more important than any other known cassava disease.

Effective control measures for this disease must be developed and promoted to reduce its effects. If uncontrolled, this new root rot of cassava is likely to disrupt food security in the region. The host range of *P. sulphureus* is wide. A number of important tree species are hosts to this parasite.

This paper reports research results aimed at obtaining information regarding this new root rot disease of cassava and the efforts being made towards its control.

Materials and Methods

Distribution of the disease. Annual surveys were conducted in the dry and wet seasons of 1999, 2000 and 2001 under the Integrated Pest Management Component of the National Root and Tuber Improvement Programme (RTIP) of Ghana to quantify incidence and severity of the major diseases of cassava and provide information on new diseases and their spread in the country. In addition to these

general surveys, localized surveys were conducted in areas where *Polyporus sulphureus* attacks on cassava were found or reported.

Screening of cultivars for resistance.

Experiments to test varieties for resistance to the fungus were set up in disease hot spot areas of Sabadu and Avemedra in the Kpando district of the Volta region. Disease incidence in these two adjacent farming communities was 80% in 2000. Ten elite cultivars in the advanced stages of the cassava breeding programme of Crops Research Institute (Kumasi, Ghana) were tested for resistance in these areas in a randomized complete block design (RCBD). A popular improved cassava variety, 'Afisiafi' and a local farmer's variety were included in the experiments as checks.

Disease progress was monitored as soon as a small fruiting body of the fungus was seen at the base of the stem of a healthy growing cassava plant. Morphological changes in both parasite and attacked cassava plants were documented throughout the 18 months crop cycle. Features of storage roots were recorded at harvest and losses due to rots quantified. In addition to the root rot disease, the reaction of the genotypes to all the major diseases of cassava were assessed on a 1-5 scale (where 1= no visible disease symptom observed; 5= symptoms of disease depicting severe damage to tissues organs). Disease development was also monitored on farmers' fields. Local farmers were involved in the evaluation of the genotypes for disease resistance.

Host range. Host range of the pathogen was determined in endemic areas through surveys. The roots of attacked secondary host plants were exposed to establish the type of association or linkage that exist between host and parasite.

Cultural Practices. Cultural practices that promoted spread and persistence of the root rot disease in the endemic areas were identified. Farmer practices like methods of

land preparation, source of planting materials, handling of harvested storage roots and handling of plant debris after harvest were recorded. Selection of planting materials for cuttings was also investigated.

Workshops and Farmer Field Days.

Workshops and Farmer Field Days were organized for farmers and Agriculture Extension Agents (AEAs) in disease hot spot areas in the Kpando District of the Volta region. These activities were used to increase farmer s aware of cassava diseases. In these activities, farmers and AEAs were trained in disease identification and their control. A television documentary on the root rot disease was prepared from workshops and field days for awareness creation.

Results

Distribution of the disease. Results of surveys indicate the presence of the disease in Ashanti, Volta, Central, Greater Accra and Eastern regions of Ghana. Districts with significant presence of the disease identified in the surveys were Kpando, Ho, Ejura-Sekyeré Dumase, Awutu, Swedru and Gomoa districts. The highest incidence of 33% was recorded in the Kpando district of the Volta region. Avemedra and Sabadu farming area

in the Kpando district had the highest incidence of the root rot disease (80%) in 2000. A survey of the same area in the wet season of 2002 showed a drop in disease incidence from 80 to 50%.

Disease development and yield loss. The first sign of the disease is the appearance of the fruiting body of the basidiomycete on the distal end of the stem of an attacked cassava plant. In endemic areas new attacks on farms are observed soon after the first rains following the prolonged dry season. The bright yellow fruiting body develops rapidly and can expand to 30 cm in diameter in less than 4 weeks. The fruiting body persists on the attacked plant for weeks. It may shrink in size and finally become a dry brown leathery tissue attached to infected cassava plant. Depending on the variety of cassava, wilting and defoliation may be observed several weeks after the initial attack. Harvested roots from the defoliated plants are often completely rotten.

Screening for resistance. Results from the resistance screening experiments are shown in Table 1. The genotypes TME 1, TME 6 and 91/02324 were not affected by the root rot organism. All other genotypes suffered yield losses due to the root rot disease. Yield losses

Table 1: Reaction of elite cultivars of cassava to tuber rot (caused by *P. sulphureus*) and the other major diseases of cassava (figures represent disease severity scores on a 1-5 scale).

Genotype	ACMV	CBB	CAD	BLS	Root rot
TME 1	1.0	1.0	4.0	3.0	1.0
TME 5	1.0	1.0	3.0	3.0	3.0
TME 6	1.0	1.0	4.0	3.0	1.0
TME 11	1.0	1.0	4.0	3.0	3.0
TME 12	1.0	1.0	4.0	3.0	2.0
TME 14	1.0	1.0	4.0	3.0	2.0
91/03227	1.0	1.0	4.0	3.0	2.0
91/02324	1.0	1.0	5.0	3.0	3.0
182/0328	1.0	1.0	4.0	3.0	2.0
92/0398	1.0	2.0	3.0	3.0	3.0
'Afisiati'	3.0	1.0	3.0	3.0	3.0
Local	4.0	1.0	3.0	3.0	3.0

ranged between 2 and 50% among the susceptible genotypes. TME 5 and TME 11 were the most severely affected.

Host range. Observations made so far confirms that the root rot causal organism has a wide host range. The parasite attacks a number of woody trees and citrus plants. Fruiting bodies of the parasite were found attached to the roots or stems of these secondary host plants. Symptoms produced in these hosts also include wilting, defoliation and subsequent death of plants.

Discussion

This study confirms the presence of root rot caused by *P. sulphureus* (*Laetiporus sulphureus*) in Volta, Central, Ashanti, Greater Accra and Eastern regions of Ghana. There is a high incidence of the disease in the Avemedra and Sabadu areas of the Volta region and the Awutu district of the Central region of Ghana. The strong presence of the disease in the Awutu is of great concern as it is likely to affect the activities of the starch factory in this area. In addition, the major staple food for the people of Volta region is cassava. The presence of the disease in this region can undermine food security of this region. If

not contained, it may affect the exportation of cassava to other countries in the region.

It became clear from the surveys that most farmers in the country were not aware of this disease. It is important therefore, that awareness creation activities in endemic and disease free areas be intensified. Interaction between research, extension agents and farmers through workshops and field days explain the drop in the incidence of root rot in the Avemedra and Sabadu areas of the Kpando district from 80% in 2000 to 50% in 2002. A number of farmers in this district have adopted improved cultural practices.

It is advisable that plant debris and leftovers after harvest from fields that experienced root rot attacks are burnt. Burning in this case must be soon after harvest. Conscious efforts must be made to control the free movement of unprocessed roots and planting materials from endemic areas to new localities. It is advisable for farmers in endemic areas to avoid new fields with strong presence of the fungal pathogen if new land can be secured elsewhere. Continuous cropping of the same piece of land to cassava in endemic areas is seen as one way of promoting the disease. Rotating cassava with two crop cycles of cereals may reduce the incidence and spread of the disease.

The 10 elite genotypes screened for resistance remained disease free after 18 months. TME 1, TME 6 and 91/02324 that were not affected by the fungus also had good storage root yields (36, 32 and 34 t per ha). Such varieties should be promoted. More genotypes of cassava both from local and introduced sources should be screened for resistance.

The wide host range of this pathogen is significant. It simply signifies the need to continue searching for sources of resistance.

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Table 2: Yield of genotypes on test fields and estimated % yield loss due *P. sulphureus*.

Genotype	Mean yield from experimental fields	Estimated % yield loss due to <i>P. sulphureus</i>
TME 1	36.0	0.0
TME 5	28.0	35.0
TME 6	33.0	0.0
TME 11	24.0	34.0
TME 12	26.0	6.0
TME 14	27.0	2.0
91/02327	28.0	8.0
91/02324	34.0	0.0
182/0326	34.0	14.0
92/0398	13.0	20.0
'Afisiati'	17.0	27.0
Local	19.0	18.0

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Breeding efforts to develop high-yielding, multiple pest-resistant sweetpotato germplasm in Uganda

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Abstract. Uganda is among the largest producer of sweetpotato worldwide. However, major constraints to increased sweetpotato productivity in the country and in East Africa in general include, declining soil fertility, poor yielding varieties of low nutritive value (low dry matter and low or no β -carotene), shortage of high quality planting materials, marketing problems, and limited range of processing and utilization options, leading to high post harvest losses, estimated between 30-35%, sweetpotato weevils, and sweetpotato diseases, mainly sweetpotato virus disease (SPVD), and *Alternaria* blight. Resistances to the major diseases and pests must be combined in a common background to develop sweetpotato cultivars preferred by consumers and farmers. Uganda's sweetpotato research program has released twelve cultivars that include five land race varieties and seven improved varieties. The released cultivars have high field resistance to SPVD and *Alternaria* blight in a high dry matter (about 30%) and good taste background, and one of the cultivars has orange-fleshed (high β -carotene) storage roots. Modified recurrent mass selection coupled with sequential selection schemes, and intense selection rates of 0.2-11% to handle large numbers of generated populations from polycross nurseries has been successful in developing sweetpotato germplasm with resistance to SPVD and

Alternaria blight but not weevil resistance. In a high SPVD pressure location, progeny generated from families with parents of white-fleshed roots, and families with parents that have white- and orange-fleshed storage roots, the ratio of progeny with orange-fleshed roots to the total number of progeny ranged between 0.0 and 1.0. The segregation ratio is a rough indication that progress can be rapid in breeding cultivars with high β -carotene (orange flesh colour) that must be crossed to parents with high dry matter and resistance to SPVD and *Alternaria* blight to incorporate the latter traits.

Introduction

Sweetpotato, (*Ipomoea batatas* (L. Lam.)), annual production from 414,000 – 572,000 ha in Uganda ranges between 1.7 – 2.5 million tons. This production ranks Uganda Africa's largest producer of the crop and second after China in the world (FAO, 2003). In Uganda, sweetpotato plays an important role in the diet and food security of the population as indicated by the high per capita consumption, 85 kg/cap/year (International Potato Center, 1999). Sweetpotato is the most important food crop in the country after cooking bananas and cassava (Bashaasha *et al.*, 1995). It is increasingly playing a significant role as a ready source of cash income from sale of storage roots, vines and processed products

in rural and urban markets. However, sweetpotato yields in the country are very low (4.4 t/ha) compared to yields of over 20 t/ha (24 t/ha, 32 t/ha for Japan, and Israel, respectively (FAO, 2003). To date major constraints to increased sweetpotato productivity in Uganda and in East Africa in general include, declining soil fertility, low yielding varieties of low nutritive value (low dry matter and low β -carotene content), sweetpotato diseases [mainly sweetpotato virus disease (SPVD), and *Alternaria* blight], pests, (mainly, sweetpotato weevils), genetic erosion, shortage of high quality planting materials, marketing problems, and limited range of processing and utilization options, leading to high post harvest losses, estimated between 30-35% (Woolfe, 1992).

Resistances to the major diseases and pests must be combined in a common background to develop sweetpotato cultivars preferred by consumers and farmers. Uganda's sweetpotato research program has released twelve cultivars that include five local landraces and seven improved varieties. The released cultivars have high field resistance to SPVD and *Alternaria* blight in a high dry matter (about 30%) and good taste background, and one of the cultivars has orange-fleshed (high β -carotene) storage roots (Mwanga *et al.*, 2001a, 2003). The major sweetpotato breeding objectives at NAARI are: (1) develop germplasm with desirable traits (2) combine the desirable traits with multiple resistance, namely, resistance to SPVD, *Alternaria* stem blight and sweetpotato weevil. This paper highlights the procedures that have led to the release of the improved high yielding, multiple-resistant sweetpotato germplasm in Uganda. Modifications to improve selection rates, and results are presented and discussed.

Materials and Methods

The following approaches have been used to develop sweetpotato cultivars with multiple-pest resistance:

Germplasm evaluation and breeding. The initial step at NAARI in 1987 to 1989 was to screen a total of 380 out of 450 sweetpotato landrace accessions assembled in 1986 as previously described (Mwanga *et al.*, 1991; Mwanga and Otim-Nape, 1992). Superior landrace entries were subsequently evaluated with promising clones screened from base (source) populations generated at NAARI and tested in Uganda's major agroecologies as reported (Mwanga and Mateeka, 1994). A total of 259 introductions imported in different batches, mainly as pathogen tested in vitro plantlets from mainly the International Potato Center (CIP), Lima, Peru, and to a less extent the USA, and the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were field-tested with emphasis on resistance to SPVD between 1989 and 2003.

Generation of breeding populations and screening. The base (source) populations were obtained from: 1) local and introduced germplasm and 2) improved populations and families generated from polycross nurseries. Most of the source populations were generated by polycrosses that were open-pollinated mainly by honeybees and hand crosses of specific male and female parents to combine virus resistance and other desirable traits as previously described (Mwanga and Mateeka, 1994). A total of 18-24 promising local landraces and improved clones selected from source populations were used as parents in the polycrosses. A new combination of parents formed a new polycross nursery each year between 1989 and 2003.

Selection scheme. The recurrent selection used for population improvement was half-sib family testing and selection between and within families. Mass selection was used for screening for virus resistance. Basically, the selection system is a modification of recurrent mass selection coupled with sequential selection schemes developed by Jones *et al.* (1986) and Hahn (1980). The source

populations were screened and advanced through seedling nursery (around 100,000 seedlings at the start), clonal evaluation, preliminary, intermediate, advanced, and on-farm yield trials before release, lasting 7-8 years (two seasons per year) to 14-16 years (one season per year). Rigorous screening for SPVD resistance, 0.2-11% selection rate was used in the early cycles of selection, seedling nursery, clonal evaluation, and preliminary yield trials (Mwanga *et al.*, 2000, 2001).

Generation of breeding populations and selection for increased β -carotene.

To obtain a rough idea of prediction based on choice of sweetpotato parents to increase β -carotene in storage roots, segregation of orange flesh colour in the roots was recorded in progeny of parents with white flesh, orange flesh roots or both. Flesh colour of storage roots was recorded in the following seedling families at 5 months after planting in November 2002:

- 1) families generated from specific crosses of parents previously selected for white flesh and high dry matter
- 2) families raised from open pollinated seed of parents with white flesh storage roots previously selected for white flesh
- 3) families raised from open pollinated seed of parents with orange flesh and white flesh roots
- 4) families raised from specific crosses of parents with orange, yellow, cream or white flesh.

The segregation ratio of number of seedlings with orange flesh colour (OFC) to the total was computed for the four types of seedling families.

SPVD resistance evaluation. SPVD was screened in the field and confirmed in the greenhouse. SPVD is due to dual infection by *sweetpotato feathery mottle potyvirus* (SPFMV) transmitted non-persistently by aphids and *sweetpotato chlorotic stunt crinivirus* (SPCSV) transmitted semi-persistently by the whitefly (*Bemisia tabaci*). Field resistance to SPVD was confirmed by

graft-inoculation using SPVD-infected scion and the test genotype as stock. Double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) and triple antibody sandwich antibody sandwich immunosorbent assay (TAS-ELISA) were used to detect SPFMV and SPCSV, respectively, as previously reported (Mwanga *et al.* 2002a). Test plants giving negative results in serological tests were grafted on the indicator plant, *Ipomoea setosa* to confirm freedom from viruses as previously described (Mwanga *et al.*, 2002b).

Selection under high and low SPVD pressure.

Breeding efforts to date in the country to produce orange-fleshed sweetpotato [OFSP (high in beta carotene/ Vitamin A)] cultivars have focused on generation of improved clones for release. Based on one of the most severe constraints to sweetpotato production, sweetpotato virus disease (SPVD), large numbers of the base (source) populations (50,000-100,000 genotypes) are required to start a screening cycle in high virus pressure areas. The number of genotypes selected in the early cycles of selection is always between 1-15%. To establish whether efficiency of selection for SPVD resistance in different agroecologies would be improved by using an extra site with low virus pressure, a set of trials (seedling, observational, clonal and diallel) were planted at NAARI in 2002. The selection rates in the different trials based on SPVD were recorded. In the first season of 2003, seeds of 40 families (807 genotypes) were planted at Serere Agricultural and Animal Production Research Institute (SAARI), a low SPVD pressure environment. In the same season at NAARI, a high SPVD environment, 93 families (3,620 genotypes), including the 40 families planted at SAARI, were planted at NAARI, and selection rates at the two sites (NAARI and SAARI) were established.

Genetics of SPVD resistance and DNA markers. The genetics of SPVD resistance and markers was investigated using full-sib

families generated from 10 parents crossed in half diallel as previously described (Mwanga *et al.* 2002b). Control of resistance to SPCSV and SPFMV being mediated by genes was investigated using randomly amplified polymorphic DNA (RAPD) and amplified fragment length polymorphisms (AFLP) as previously described (Mwanga *et al.*, 2002a).

Alternaria blight resistance evaluation. Sweetpotato germplasm and breeding populations were screened for resistance to *Alternaria* blight as previously described (Mwanga *et al.* 2001a, b).

Field and laboratory rating tests for sweetpotato weevil resistance. Resistance of germplasm and breeding populations was rated routinely in breeding trials on a subjective scale of 1-5, where 1 = no damage, and 5 = total damage. This screening was not efficient when weevil populations were high. The resistance of recently introduced sweetpotato clones to sweetpotato weevils, *Cylas puncticollis* and *C. brunneus*, the most damaging pests of the crop, was not known in Uganda. Therefore, field studies were carried out at Serere Agricultural and Animal Production Research Institute (SAARI), to establish the extent to which the introduced sweetpotato clones differed in susceptibility to field infestation by *Cylas* spp. Two field trials were conducted between September 2000 and May 2001, in which 27 sweetpotato clones from USA and CIP, Lima, were screened in a randomized complete block design (RCBD) with four replications. Two laboratory tests with three replications each were conducted at NAARI in June - September and December 2001 - March 2002, to relate infestation and damage levels obtained from field trials to laboratory results. Data were collected on time (days) of F₁ generation emergence, and total number of weevils emerged.

Results and Discussion

Germplasm screening and breeding. Five sweetpotato cultivars (New Kawogo, Tanzania,

Tororo 3, Wagabolige, and Bwanjule) screened from the 380 local landrace cultivars and one breeding line (Sowola) were released in 1995 (Mwanga *et al.* 2001). Approximately 300,000 seedlings were screened between 1989-1995 of which Sowola was the only cultivar released. Six more cultivars (NASPOT 1 to NASPOT 6), including an orange-fleshed one (NASPOT 5) were released in 1999 (Mwanga *et al.* 2003). The combination of the released cultivars has good storage shapes, high dry matter content (>30%), high consumer acceptance, moderate to high levels of field resistance to SPVD and *Alternaria* blight, and high root yields compared to the average national root yield average of 4 t/ha (CIP, 1999). Of interest to multiple resistance, Cervantes-Flores *et al.* (2002) at North Carolina State University, Raleigh, USA, found two of the released cultivars, Wagabolige and Tanzania resistant to all three nematode species tested. The nematode species evaluated were *Meloidogyne arenaria* (Neal) Chitwood (two races), *M. incognita* (Kofoid and White) (four races), and *M. javanica* (Treub) Chitwood.

A total of 220 improved sweetpotato cultivars and breeding lines from CIP, USA, and IITA (Table 1 and 2) were field tested as received in different batches between 1989 and 2003 at NAARI in Uganda. Except for Naveto and Huarmeyano (CIP 420020) that exhibited moderate field resistance to SPVD, all the introduced accessions degenerated under natural SPVD pressure within one to three seasons of testing. The implication is that for any of the introduced genotypes to be grown in the farming system in the high SPVD agroecology, there is need to supply virus-free material every season or every time the cultivars degenerate.

Selection of promising clones resistant to SPVD. The number selected of sweetpotato clones resistant to SPVD and *Alternaria* blight was small in all breeding trials, especially in the early cycles of selection throughout the years of evaluation. The selection rate, for example in the different trials in 2002 varied

Table 1: Sweetpotato germplasm introductions (*in-vitro* material) from CIP evaluated at NAARI, Uganda 1989-1999.

Code	CIP No.	Code	CIP No.	Code	CIP No.	Code	CIP No.	Code	CIP No.
1	187001.1	36	420064	71	440049	107	440107	142	440222
2	187001.21	37	420065	72	440055	108	440111	143	440223
3	1870004.1	38	420066	73	440056	109	440122	144	440226
4	187004.2	39	420068	74	440057	110	440113	145	440237
5	187012.12	40	420091	75	440058	111	440120	146	440239
6	187016.2	41	420093	76	440059	112	440121	147	440240
7	187018.1	42	440001	77	440060	113	440122	148	440242
8	1880021.1	43	440002	78	440062	114	440123	149	440243
9	188004.2	44	440004	78	440063	115	440127	150	440244
10	400001	45	440005	80	440066	116	440129	151	440248
11	400004	46	440006	81	440067	117	440130	152	440252
12	400005	47	440007	82	440070	118	440137	153	440254
13	400009	48	440009	83	440071	119	440138	154	440255
14	400010	49	440014	84	440072	120	440143	155	440258
15	400016	50	440020	85	440073	121	440144	156	440263
16	400018	51	440021	86	440074	122	440149	157	440281
17	400020	52	440022	87	440075	123	440150	158	440283
18	400025	53	440023	88	440077	124	440151	159	440287
19	420004	54	440024	89	440078	125	440154	160	440288
20	420008	55	440025	90	440080	126	440158	161	440293
21	420017	56	440027	91	440082	127	440159	162	440303
22	420018	57	440029	92	440084	128	440160	163	440313
23	420020	58	440030	93	440085	129	440164	164	440333
24	420021	59	440031	94	440086	130	440176	165	440337
25	420023	60	440034	95	440087	131	440189	166	440374
26	420024	61	440036	96	440088	132	440194	167	440376
27	420025	62	440037	97	440089	133	440197	168	440377
28	420026	63	440038	99	440090	134	440199	169	440380
29	420028	64	440040	100	440092	135	440200	170	440384
30	420030	65	440041	101	440093	136	440201	171	440386
31	420031	69	440043	102	440096	137	440205	172	440388
32	420033	67	440044	103	440101	138	440206	173	440391
33	420038	68	440045	104	440102	139	440208	174	440342
34	420048	69	440046	105	440105	140	440215		
35	420053	70	440047	106	440106	141	440216		

from approximately 1% to 12% (Table 1), which was typical of selection rates of previous years (Mwanga and Mateeka, 1994). Natural field infection under high SPVD pressure and graft inoculation of promising families with SPVD consistently resulted in severe SPVD in all the families. The distribution of SPVD scores was skewed toward highly susceptible categories (SPVD scores 4 and 5), eliminating almost all the resistant categories (scores 1 and 2). The response of diallel progeny of 15 promising families to SPVD in 1998-2000 is

presented as an example of distribution expected of populations screened for SPVD resistance (Fig. 1). Sometimes all the evaluated populations fell in the susceptible category (score 4 and 5), resulting in discarding those populations due to high susceptibility.

Selection for increased β -carotene. The segregation of progeny for root flesh colour in 98 families (36,616) is shown in Table 3. Of the 24 families (1,198 seedlings), raised from specific crosses of parents previously

Table 2: Sweetpotato germplasm introductions (*in-vitro* material) from CIP and IITA evaluated at NAARI, Uganda 1989/90 (TIB and TIS names only) and 1999-2003.

Code	CIP No.	Name clone	Code	CIP No.	Name of clone
175	199004	CC89.147. 4 x OP	198	440076	TIS 9291
176	199004	CC89.147. 4 x OP	199	440131	Naveto
177	199005	CHGU 1.002 x OP	200	440136	Caromex
178	199015	LM92.032 x OP	201	440140	Kandee
179	199015	LM92.032 x OP	202	440141	Julian
180	199024	SR91.109 x OP	203	440157	Ningshu 2
181	199024	SR91.109 x OP	204	440170	Kemb 37
182	199025	SR92.095. 3 x OP	205	440188	Kyukei 63
183	199026	SR92.095. 8 x OP	206	440203	Unknown
184	199027	SR92.095. 10 x OP	207	440218	101274
185	199034	SR95.628 x OP	208	440228	CARI 9
186	199035	SR95.636 x OP	209	440229	CARI 426
187	199036	SR95.636 x OP	210	440236	CN1831-14
188	199036	SR95.636 x OP	211	440264	WON 1
189	199036	SR95.636 x OP	212	440443	Nashu 88 (81-88)
190	199057	LM94.422 x OP	213	556638	Jewel
191	199062	SPV 78.001. 3 x OP	214	-	Blesbok
192	420005	Nemanete	215	-	Mafutha
193	420009	Japon Tresmesino	216	-	TIB10(3)
194	440010	W-215	217	-	TIS5125
195	440016	Excel	218	-	TIS5801
196	440018	W-223	219	-	TIS82/0395
197	440069	TIS 5125	220	-	TIS83/170

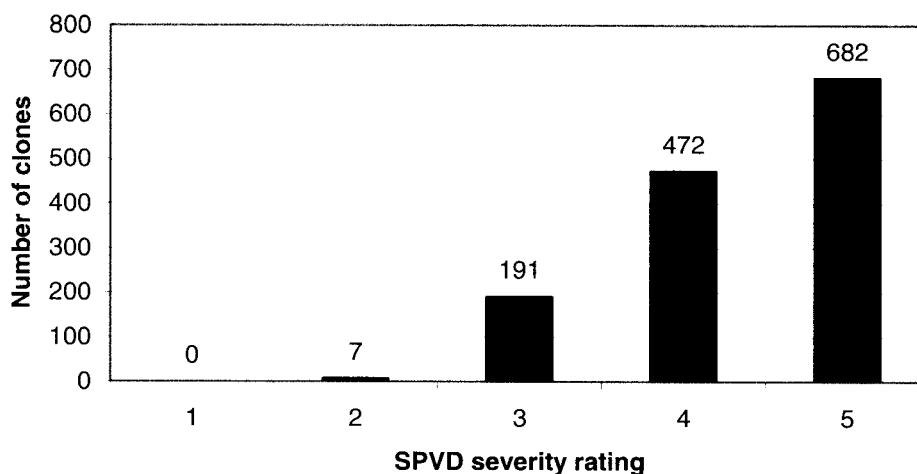


Figure 1: Frequency distribution of sweetpotato virus disease (SPVD) severity scores among 15 promising diallel families (1352 genotypes) at Namulonge Uganda, 1999-2000. SPVD severity rating, 1 = no symptoms, 5 = very severe symptoms.

Table 3: Number of entries and selection rate in some selected sweetpotato breeding trials, 2002.

Trial	Trait screened for	Number of genotypes grown	Selection	
			Number of clones	%
Seedling (pre-selection)	SPVD ¹ resistance, Alternaria resistance, high dry matter content (DMC)	70,279 ²	68,874	98
Observational	SPVD resistance, Alternaria resistance, DMC	1,270	74	5.2
OFSP ³ Clonal	SPVD resistance, Alternaria resistance, DMC, Orange flesh (high β -carotene)	137	12	8.8
Diallel cross progeny	SPVD resistance, Alternaria resistance, DMC	694	85	12.2

¹ SPVD = sweetpotato virus disease

²Number planted = 140,520 seeds were planted

³OFSP = Orange-fleshed sweetpotato.

selected for white flesh and high dry matter, none had orange flesh colour (OFC). A very small fraction, 0.009 (97 seedlings) of the 33 families (6,994 seedlings) raised in category two (open-pollinated, white-fleshed parents) had OFC. In category three (open-pollinated, OFC parents) of 15 families (17,775 seedlings), the ratio of seedlings (3,730) with OFC to the total number increased to 0.22. The ratio (0.39) of OFC to total number of seedlings was highest in the 26 families (649 seedlings) raised from specific crosses, including parents previously selected for OFC (Table 4). The segregation ratio of progeny with OFC roots to the total number of progeny ranged between 0.0 and 1.0. This segregation ratio is a rough indication that with the right choice of parents, progress can be rapid in breeding cultivars with high β -carotene (orange flesh colour). However, the improved clone must be crossed to parents with high dry matter, and resistance to SPVD and Alternaria blight to incorporate the latter traits. In all screenhouse and field evaluations none of the genotypes screened through the years exhibited immunity to SPVD.

The proportion of genotypes selected compared to NAARI under natural high SPVD pressure was significantly increased from about 1-12% to about 95% under low SPVD pressure at SAARI (Table 5). SAARI will

therefore be a second site to NAARI for seedling screening for resistance to SPVD in subsequent field evaluations to increase the proportion of selected genotypes under low SPVD environments.

Genetics of SPVD resistance and DNA markers. Graft inoculation with SPVD (SPCSV and SPCSV) of two promising families (Tanzania x Bikilamaliya and Tanzania x Wagabolige) produced severe SPVD in all progenies (294 genotypes). Inoculation of the two promising families with SPCSV and SPFMV, and Mendelian segregation analysis for resistant vs susceptible categories for the two viruses based on ELISA results suggest that resistance to SPCSV and SPFMV is conditioned by two, separate major recessive genes. In the proposed model for inheritance, the two genes are inherited in a hexasomic or tetradisomic manner (Mwanga *et al.*, 2002). Subsequent molecular marker studies yielded two DNA markers associated with resistance to SPCSV and SPFMV. The AFLP and RAPD markers linked to SPCSV and SPFMV resistance explained 70% and 72% of the variation in resistance, respectively (Mwanga *et al.*, 2002b). These AFLP, RAPD and QTL analyses suggest that, in the presence of both SPFMV and SPCSV, additional genes mediate oligogenic or multigenic horizontal

Table 4: Segregation of orange flesh colour (OFC) in storage roots of sweetpotato seedlings.

No. of families	Parental type	Number of seedlings		Ratio a:b	Range of ratio
		(a) with OFC	(b) Total		
24	Crosses (white-fleshed) parents	0	11,198	0	0
33	Open pollinated (white-fleshed parents)	97	6,994	0.01	0.01-0.07
15	Open pollinated (OFC parents)	3,730	17,775	0.21	0.04-0.67
26	Crosses + OFC parents	237	649	0.37	0.00-1.00

Table 5: Selection rates in orange-fleshed families at Namulonge Agricultural Research Institute (NAARI) and Serere Agricultural and Animal Production Research Institute (SAARI), Uganda in 2003.

Location	Number of families	Number of seedlings	Selection	
			No. of seedlings	%
NAARI (high virus pressure)	93	3,620	325	9.4
SAARI (low virus pressure)	40	807	770	95.4

eggs laid in storage roots developed into adults. From previous studies, for *Cylas brunneus*, this period covered 32-41 days. The antibiosis study (no-choice experiment) revealed that clones such as Ivoire, TIS 8266, Kemb37, Zapallo and NC196-20 with delayed and low emergence of weevils could be good clones in the national breeding program as sources of weevil resistance (Fig. 4). However, the same clones with delayed and low weevil emergence, exhibited greening and sprouting storage roots. The physiological processes of greening and sprouting could have affected weevil emergence, since phytoalexins produced during greening are toxic to weevils.

These results are similar to results reported in literature, where despite years of extensive screening, no highly resistant germplasm is currently available for weevil control (Mullen *et al.*, 1985; Thompson *et al.*, 1999). Production losses due to weevil feeding may often reach 60% to 100% (Stathers *et al.*, 2003). The search for host resistance to SPW in the sweetpotato germplasm has yielded no reliable result

worldwide. The use of biotechnological approaches to introduce 'resistance genes', therefore, holds the greatest promise to protect sweetpotato against weevils. According to Matin Qaim (2001), weevil resistance technology would create welfare gains of 9.9 million US \$ and estimated internal rate of return on biotechnology research investment of between 33 to 77%. Therefore, the most practical way to rapidly incorporate resistances into sweetpotato is by plant transformation (Prakash and Varadarajan, 1992).

Scientists conversant with the SPW problem believe that the use of Bt genes, *Bacillus thuringiensis*, currently represents the most feasible means of achieving sustainable control under African farming systems. The identification and transfer of genes that produce a protein that is toxic to weevils represents such an approach. Crops containing Bt genes are the second most widely grown transgenic plants. To date, a body of experience has been achieved that confirms the safety of Bt to human health, its

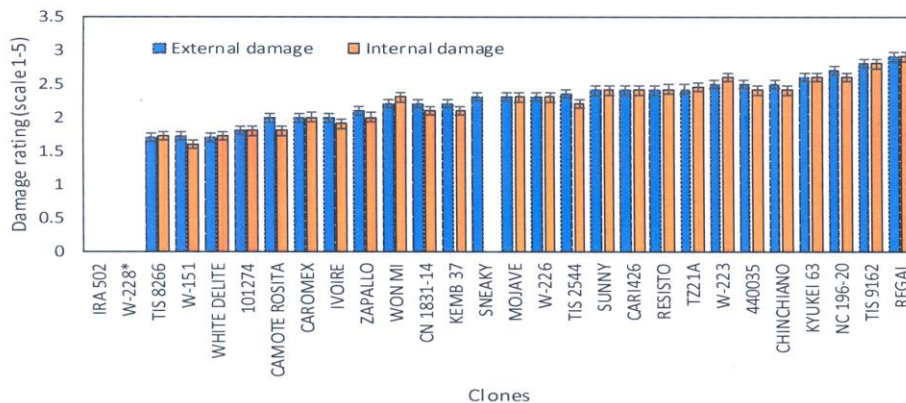


Figure 2: External and internal damage of vines of sweetpotato clones at SAARI, 2000 season. *No data available due to destruction of clones by sweetpotato virus disease.

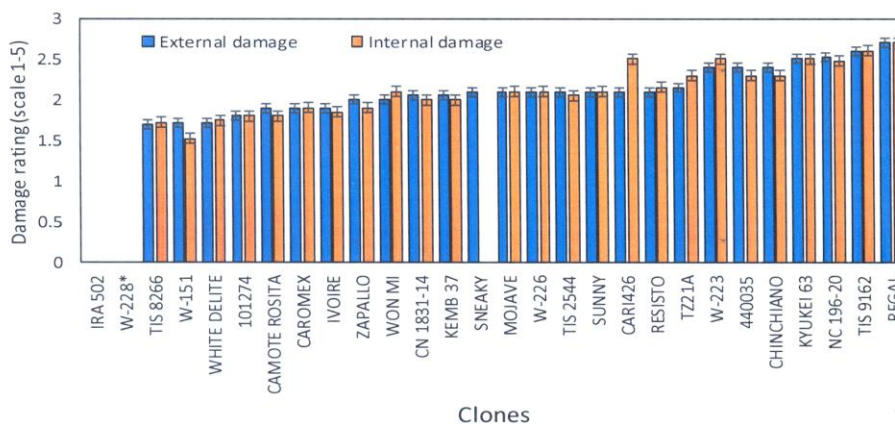


Figure 3: External and internal damage of vines of sweetpotato clones at SAARI, 2001 season. *No data available due to destruction of clones by sweetpotato virus disease.

(Quantitative) effects in the progenies studied for resistance to SPVD.

Resistance to Alternaria blight resistance. Efficiency of screening sweetpotato germplasm and breeding populations for resistance to Alternaria blight depended on prevalence of the disease under field conditions. Ideal conditions for screening

were during wet and humid seasons in the different agroecologies and more ideally at high altitude. Released cultivars Bwanjule, Sowola, NASPOT 3, NASPOT 5 and NASPOT 6 exhibited moderate to high field resistance to Alternaria blight. The other cultivars were susceptible to the disease and were therefore adapted to warm agroecologies where the disease was not severe.

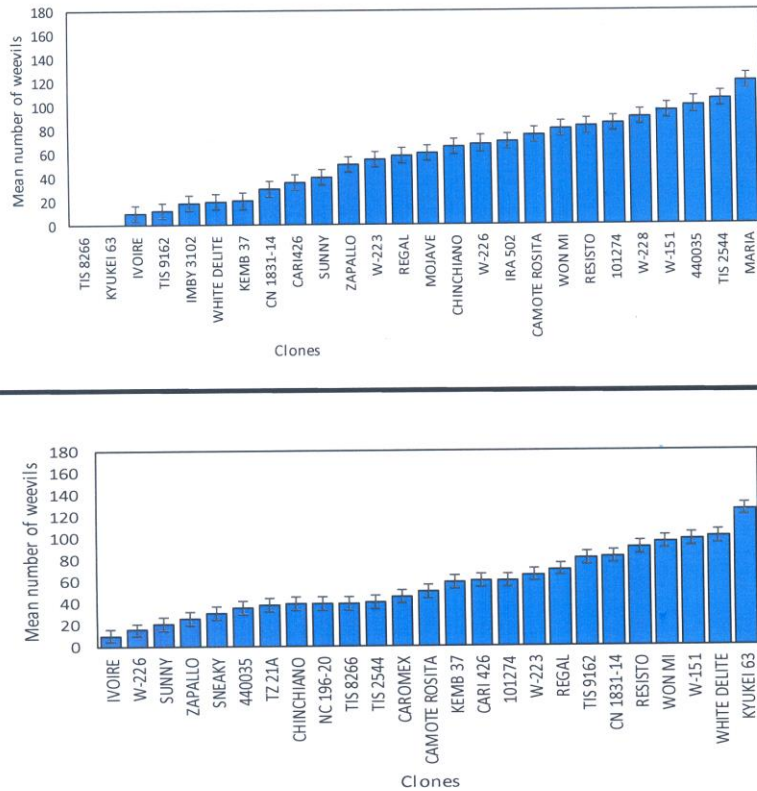


Figure 4: Mean number of adults of *Cylas brunneus* adults emerging from single roots of sweetpotato clones during 11-week emergence period in 2001 (upper graph) and 2002 (lower graph).

Field and laboratory rating tests for sweetpotato weevil (SPW) resistance. In all breeding trials there were differences in susceptibility to SPWs in the field under low weevil populations. However, under high weevil pressure all clones were equally infested. Introduced clones were observed for their reaction to SPWs. Clone Ivoire exhibited some evidence of shoot resistance in field and root resistance in laboratory tests as compared to Tanzania (local check), due to possibly antibiosis mechanism of resistance. None of the clones, including Ivoire showed consistent high resistance ratings in field and laboratory experiments in the two tested seasons (Figs. 2-4). High number of soil cracks

on mounds significantly ($P < 0.05$) increased the numbers and weights of infested storage roots per plant due to increased access to the storage roots by the weevils. There was also a positive association between the number of storage roots and the number of soil cracks on mounds attributed to the increased pressure within the mound from the bulking of storage roots (data not shown).

Weevil emergence peaked during the seventh week. The experiments for both seasons were conducted up to 18 weeks but data is presented for only the first 11 weeks to exclude second-generation adult weevil counts. There was no weevil emergence from week one to four. This was the period when

positive impact on the environment, and its effectiveness in controlling highly targeted pests (Betz *et al.*, 2000; Shelton *et al.*, 2002).

Conclusions

Good progress has been made in Uganda in breeding sweetpotato with multiple resistance, particularly resistance to sweetpotato viruses and *Alternaria* stem blight. These resistances can be incorporated in genotypes with desirable traits but are susceptible to any of the diseases using conventional breeding. To date, however, despite intense global search for resistance, no highly resistant germplasm is currently available for sweetpotato weevil control. Therefore, the most practical way to rapidly incorporate resistances into sweetpotato is by plant transformation using Bt genes.

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Production potential of root and tubers in association with plantation crops

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Abstract. In India tropical root and tuber crops namely cassava, greater yam, lesser yam, elephant foot yam, taro, tannia and arrowroot are mostly cultivated in association with plantation crops like coconut, arecanut, coffee, rubber and banana. Intercropping the root and tubers with tree crops both at the immature and mature phases is a common practice especially in small and medium sized land holdings, in order to augment the net income and employment opportunities. In such farms, the produce from the perennials generates the cash income, while the starchy root and tubers partially meet the food requirements of the farm family and the feed needs of farm animals. Research during the past two decades in India had brought out the agronomic and economic advantages of the cropping systems involving tropical root and tubers and the plantation crops. In this paper the opportunities, challenges and future research needs of cropping/farming systems involving tropical tuber crops and perennials are critically evaluated.

Introduction

Cultivation of tropical root/tuber crops viz. cassava, yams, edible aroids and sweetpotato in the interspaces of perennial plantations (coconut, arecanut, rubber, coffee, banana etc.) is a common practice throughout the humid tropics. In the coconut and arecanut gardens of South India, cassava, yams and edible aroids are preferred as intercrops (Nayar, 1995). In Sri Lanka and Philippines also cassava is grown as intercrop in coconut plantations (Liyanage and Dassanayake,

1993). Rubber plantations of India are intercropped with cassava, yams and edible aroids during the immature phase (Mathew *et al.*, 1978) whereas in Malaysia cassava is grown as intercrop in rubber estates (Leihner, 1983). In juvenile robusta coffee plantations, elephant foot yam, greater yam and ginger are grown in the interspaces (Nayar, 1976). Intercropping banana orchards with yams and edible aroids is also a profitable practice (Nayar and Nair, 1992).

According to one school of thought these perennial plantation crops cum annual root/tuber crop systems had developed due to the human population pressure on arable land, especially in the tropics. On the contrary such systems are more efficient for the optimum utilization of resources viz., land, water, solar radiation and other inputs. The root and tuber crops other than sweetpotato have longer duration than cereals and are adapted to the same ecological conditions suitable for plantation crops. In plantation crops cum root and tuber crops farming systems the main crop provide the cash income for the farmer, while the intercropped root and tubers partially meet the food requirements of the farm family and the livestock.

Though intercropping in plantations is an age-old practice, in India, systematic research had been taking place only during the last two decades, mainly to refine the system and enhance productivity. Willey (1979) had postulated three different situations under intercropping. (i) Intercropping must give the full yield of the main crop and some yield of the companion crop (ii) The combined yield of the crops must exceed the higher sole crop

yield (iii) Combined intercrop yields must exceed the combined sole crop yields. In cropping systems research involving the plantation crops and root/tubers, only the first situation is considered. In this paper the salient research achievements and future research needs of cropping / farming systems involving tropical root/tubers and perennials are critically evaluated.

Resource use in plantation crops. Most of the plantation crops occupy the land for several decades and utilize the natural resources only to a very limited extent producing less than 10% of the potential dry matter production in the tropics (Nelliat *et al.*, 1974). Roots of coconut trees planted at the recommended spacing of 7.5 x 7.5 m effectively use only 25% of the land and the canopy intercepts about 40 to 50% of the solar radiation at mature stage. (Nair and Balakrishnan, 1976). Arecanut palms spaced at 2.7 x 2.7 m exploit only 50% of the land and about 50 to 75% of the solar radiation (Nelliat, 1979). In other perennial crops also (rubber, robusta coffee, banana etc.) which are planted at wider spacing, resources like land and solar radiation are not fully utilized. In addition to land and solar radiation one of the most important requirements for intensive cropping is water. In general, the water requirement of crops by and large depends on the evaporative demand of the climate of the location. So the quantity of water required to facilitate production of single crop or a number of crops in a particular location would remain almost same. Analysis of the above features of plantation crops clearly suggests the agronomic and economic advantages of raising compatible crops in the interspaces. Strengths and weaknesses of root and tubers as intercrops

The desirable traits for crops suitable for growing in the interspaces of plantation crops have been suggested by Allen (1955) and Hartley (1977). Such crops should be shade tolerant, should not overgrow the main crop, and should not host the same pests and diseases of the main crop. The cultural

operations for the intercrop should not damage the main crop or promote soil erosion, its economic life should not exceed that of the main crop, and should be adapted to the same ecological conditions. In addition, the produce should have good storability and be marketable.

On critical evaluation of the characteristics of the root and tubers, it may be observed that root and tuber crops especially edible aroids and arrowroot are shade tolerant, most are shorter in stature and are comparatively tolerant to pests and diseases and do not harbour common pests and diseases. The root and tuber crops are adapted to the same ecological conditions as that of plantation crops and have shorter duration, their produce have fairly good storability and all of them have demand in local markets. However, their export potential and scope for value addition is limited and their production involve land disturbance, which may promote soil erosion especially in sloppy terrain.

Effects of intercropping with root and tubers on plantation crops

The long-term implications of intercropping with root and tubers in coconut and arecanut plantations were studied in detail. Intercropping experiments in coconut stands with tubers revealed that raising tuber crops had no adverse effect on the main crop of coconut provided the same intercrop was not grown in the same land every year and both the intercrop and main crop were manured separately and adequately. Five to fifteen per cent increase in yield of coconut palms were obtained when cassava, elephant foot yam, greater yam, lesser yam and taro were grown in rotation (Varghese *et al.*, 1978). A number of field experiments were conducted in different locations to assess the effects of intercropping with root and tubers in arecanut gardens. The experimental evidences in general indicated that intercropping in arecanut gardens was not harmful to the main crop (Muralidharan and Nayar, 1979). The influence of intercropping tuber crops on the

growth and development of robusta coffee was studied by Nayar (1976) and reported that intercropping with elephant foot yam promoted the growth of coffee plants. The effects of raising tuber crops viz. elephant foot yam, greater yam, lesser yam, tannia and white yam on growth, yield attributes and yield of banana var. Nendran (Musa AAB) and banana var. Robusta (Musa AAA) were investigated in detail and found that the above parameters were not adversely affected due to intercropping. (Nayar and Suja, 1996; Nayar and Suja, 1998; Nayar *et al.*, 2000).

Performance of root and tubers as intercrops in plantations

The performance of root and tubers as intercrops in coconut, arecanut, coffee, rubber and banana plantations were evaluated in detail. Research to standardize the agronomic practices including soil fertility management was also undertaken especially for production of roots and tubers in association with coconut palms.

Productivity of root and tubers in association with coconut palms. The compatibility of tuberous crops viz. cassava (*Manihot esculenta*), elephant foot yam (*Amorphophallus paeoniifolius*), greater yam (*Dioscorea alata*), lesser yam (*Dioscorea esculenta*), sweetpotato (*Ipomoea batatas*),

tannia (*Xanthosoma sagittifolium*), taro (*Colocasia esculenta*) and Chinese potato (*Solenostemon rotundifolius*) were investigated in detail (Menon and Nayar 1978; Varghese *et al.*, 1978). Further Nayar (1986) investigated the production potential of cassava genotypes intercropped in coconut gardens as influenced by different plant populations, growth regulators and soil fertility management. The performance of yams particularly the recently introduced white yam (*Dioscorea rotundata*) as intercrop in coconut gardens was assessed by Nayar and Suja (1999) and Suja (2001). The productivity of arrowroot (*Maranta arundinacea*) intercropped in coconut garden as affected by plant population, mulching and N:K fertilization was studied by Suja *et al.* (2003). The information on productivity of root and tubers in association with coconut palms is summarized and provided in Table 1. In general indigenous yams, edible aroids and cassava produced satisfactory intercrop yields. The impact of coconut shade on per plant yields and estimated reduction / increase in yield is given in Table 2. Comparatively higher yield reduction was recorded for sweetpotato (47%) followed by cassava (33%) and white yam (29%).

Management practices for root and tubers intercropped in coconut gardens. Gopalasundaram and Nelliat (1979) stated that

Table 1: Productivity of root / tuber crops in association with coconut palms.

Crops	As intercrop		As sole crop	
	Plants ha ⁻¹	Yield (t ha ⁻¹)	Plants ha ⁻¹	Yield (t ha ⁻¹)
Cassava	9,000	14	12,000	28
Elephant foot yam	8,000	15	12,000	25
Greater yam	9,000	17	12,000	32
Lesser yam	12,000	10	17,000	17
White yam	9,000	16	12,000	34
Tannia	9,000	6	12,000	12
Taro	21,000	6	30,000	10
Sweet potato	49,000	4	75,000	11
Chinese potato	45,500	6	70,000	12
Arrowroot	1,30,000	18	2,00,000	25

Table 2: Impact of coconut shade on per plant productivity of root/tuber crops.

Crop	Intercrop yieldkg plant ⁻¹	Sole crop yieldkg plant ⁻¹	Change in productivity
Cassava	1.55	2.33	-33%
Elephant foot yam	1.87	2.10	-11%
Greater yam	2.13	2.66	-20%
Lesser yam	0.83	1.00	-17%
White yam	2.00	2.83	-29%
Tannia	0.75	1.00	-25%
Taro	0.29	0.33	-12%
Sweet potato	0.08	0.15	-47%
Chinese potato	0.13	0.17	-24%
Arrowroot	0.14	0.13	+7%

when intercrops are raised in coconut gardens the main crop and the subsidiary crop should be grown following the recommended management practices (including manures and fertilizers) as for sole crops to ensure satisfactory yields and profitability. However, Nayar and Sadanandan (1992) reported that N application for cassava intercropped in coconut garden can be reduced to half (50 kg/ha) of the sole crop dosage (100 kg/ha). Pushpakumari and Sasidhar (1992) also found that for lesser yam and elephant foot yam raised as intercrop in coconut the NPK dosage can be reduced to 75% and 50% respectively of the sole crop recommendation. Suja (2001) reported that depending upon availability, FYM (10 t ha⁻¹), coir pith compost (5 t ha⁻¹) or green manure can be used as organic manure with almost equal effects for white yam intercropped in coconut garden. Apart from this, application of NPK at 80: 60: 80 kg ha⁻¹ is necessary to maintain high yields of good quality tubers especially when white yam is continuously intercropped in coconut gardens. For an intercrop of elephant foot yam in coconut garden half the quantity of FYM (12.5 t ha⁻¹) and one third of the NPK dosage (26:20:33) will be sufficient when green manuring *in situ* with cowpea is practiced (Ravindran and Kabeerathumma, 1991). The recommendations on management practices and manurial schedule for intercropping root and tubers in coconut gardens are summarized and provided in Table 3.

Performance of root and tubers in association with arecanut palms. The productivity of root and tuber crops viz. cassava, elephant foot yam, greater yam, sweetpotato, taro and arrowroot in association with arecanut palms was evaluated in a number of field experiments (Muralidharan and Nayar, 1979; Sannamarappa and Muralidharan, 1982). The data on fresh tuber/root yield and biomass production in comparison to sole crop biomass production are summarized in Table 4. Higher fresh tuber yield was obtained from elephant foot yam as intercrop in arecanut gardens. However, higher biomass production was recorded in arrowroot indicating its ability to perform well under partially shaded conditions.

Performance of root and tubers in association with other tree species. The productivity of root and tubers in association with other tree species viz. coffee, rubber, eucalyptus and *Leucaena* was also investigated. Nayar (1976) identified elephant foot yam as a profitable intercrop in robusta coffee producing an yield of 18 t ha⁻¹. Ghosh *et al.* (1987) evaluated the productivity of cassava in association with tree species like eucalyptus and *Leucaena* and found that cassava yield was reduced to 80% under eucalyptus and to 70% under *Leucaena* when compared to sole crop yield by third year. They attributed this loss in productivity mainly to competition from the tree species for nutrients and moisture in addition to shade effect. The performance of elephant foot yam,

greater yam, white yam and tannia intercropped in rubber plantation as influenced by three levels of manuring was evaluated (Nayar and Suja, 2000). Among the tuber crops higher productivity was recorded for elephant foot yam followed by greater yam (Figure 1).

Productivity of tuber crops in association with banana. Raising tuber crops in the interspaces of banana is a common practice in small holdings and homestead gardens. This practice augments net income from unit area per unit time. To evaluate the production potential of tuber crops viz. elephant foot yam, tannia, greater yam, lesser yam and white yam, in association with banana a series of field experiments were conducted (Nayar and Suja, 1996; Nayar and Suja, 1998; Nayar and Suja, 2002). The results on tuber productivity are given in Figure 2. As inter crops elephant

foot yam, greater yam and white yam performed well. The performance of lesser yam was poor. Though there was no yield reduction in tannia under intercropping, its productivity both as sole crop and inter crop was poor due to some disease of uncertain etiology (Nayar and Nair, 1992).

Management practices for root and tubers intercropped in banana. Studies conducted at CTCRI (Nayar and Suja, 1996) indicated that in between two rows of Nendran banana spaced at 3.6 m x 1.8 m, three rows of the tuberous intercrops namely greater yam or elephant foot yam could be planted at a spacing of 90 x 90 cm to accommodate 8000 plants ha⁻¹. It was also found that in such a system the farmyard manure, N and P dose can be reduced to 50%. Further investigations carried out by Nayar *et al.* (2000) revealed that in Robusta banana+ Dioscorea

Table 3: Management practices for root and tubers intercropped in coconut garden.

Intercrop	Suitable variety	Method of planting and spacing	Manures		Time of planting	Duration (months)
			FYM t ha ⁻¹	NPKkg ha ⁻¹		
Cassava	Sree Visakhm H-165	Mounds 90x90 cm	9	50:50:100	May-June	8-10
Elephant foot yam	Sree Padma Gajendra	Pits 1m x 1m	20	26:20:33	April-May	8
Greater yam	Sree Keerthi	Pits 90x90cm	8	80:60:80	April-May	8
Lesser yam	Sree Latha	Pits 75x75cm	8	60:30:60	April-May	7
White yam	Sree Priya	Pits 90x90cm	8	80:60:80	April-May	8
Arrowroot	Local selection	Raised beds 30x15cm	10	50:25:75	May-June	8

Table 4: Fresh tuber yield and biomass production of root and tubers in association with arecanut palms.

Crop	Fresh root/tuber yield (t ha ⁻¹)	Biomass kg ha ⁻¹		% of sole crop
		As intercrop	As sole crop	
Cassava	10.20	-	-	-
Elephant foot yam	12.00	5046	13750	37
Greater yam	6.70	4078	12241	33
Sweet potato	0.70	1819	9904	18
Arrowroot	4.00	6580	9852	66

intercropping system about 6000 plants of *Dioscorea* can be accommodated in a hectare at a spacing of 90 x 90 cm without sacrificing the banana plant population of 2300 plants ha⁻¹ (2.4 x 1.8 m). Banana should be fertilized at the full recommended dose and for

Dioscorea 2/3 recommended level would be sufficient.

Socio economic impact. Socio economic analysis of intercropping root and tubers in plantation crops is illustrated in Figure 3. The

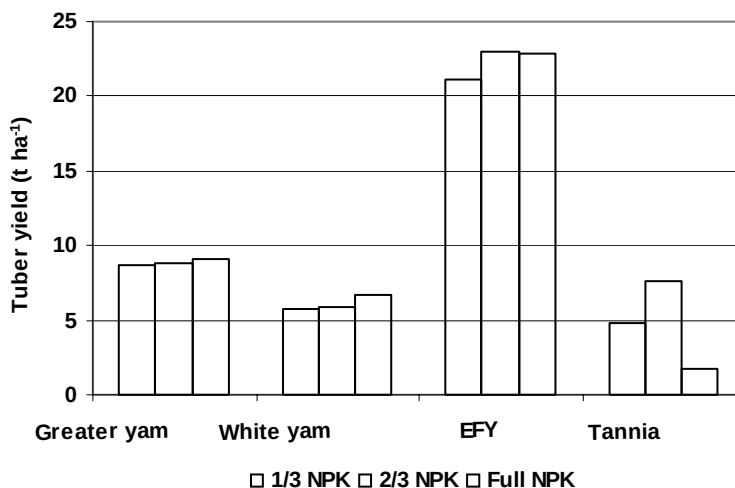


Figure 1: Effect of manuring on the yield of tuberous intercrops in rubber plantations.

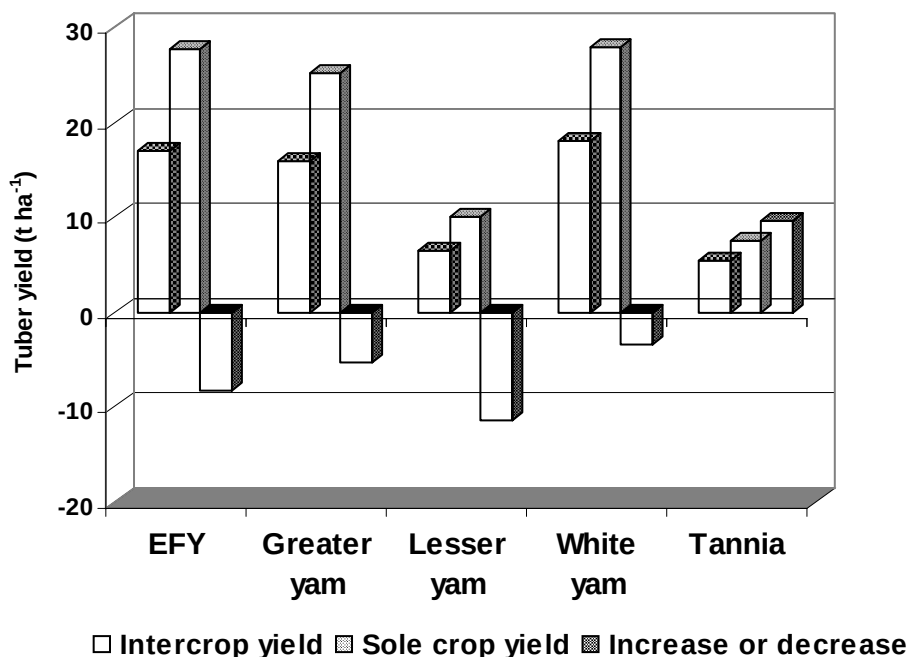


Figure 2: Productivity of tuber crops in association with banana.

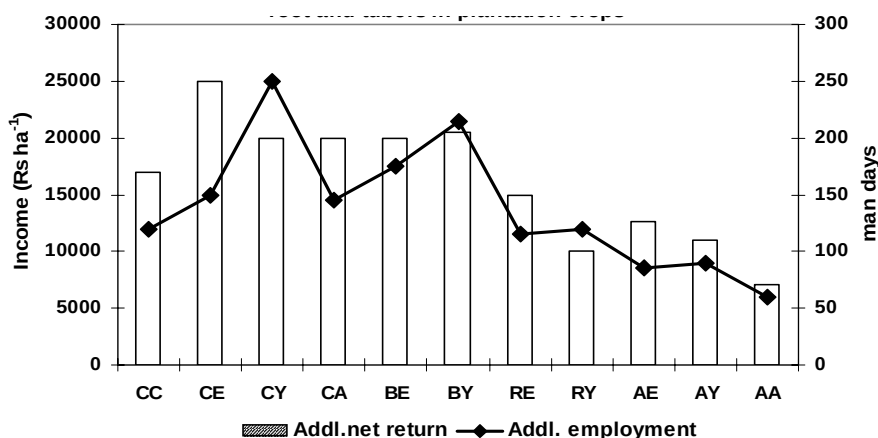


Figure 3: Socio economic analysis of intercropping root and tubers in plantation crops.

tuberous intercrops namely cassava, elephant foot yam, yams and arrowroot provide additional yield, income and employment opportunities thereby enabling sustainable livelihoods in the rural households. Besides these crops also provide high energy secondary staple to the farm family and feed to the livestock.

Future research needs

The results of research on intercropping root and tubers in perennial plantation crops have brought out very useful information especially in association with coconut palm. Technology for production of root and tubers with other perennials appears to be insufficient. More comprehensive research efforts are imperative and the following aspects require greater attention.

- (1) In view of the development of large number of high yielding varieties and hybrids in root and tubers screening them for shade tolerance/compatibility with plantation crops is needed
- (2) Standardizing the cultural and soil fertility management practices for the system considering the nutrient input and exhaust ratios

- (3) Investigations on the rooting pattern, allelopathy and synergistic effects
- (4) Assessing the soil and nutrient loss if any especially in sloppy areas
- (5) Socio-economic evaluation of the system

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Effect of altitude and plant age on cyanogenic potential, dry matter, starch and sugar content in cassava genotypes

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Abstract. A study was conducted at three locations in Uganda (Bulisa: 650 m asl; Namulonge: 1150m asl and Kapchorwa: 1750 m asl) to evaluate the effect of altitude on dry matter, starch and sugar content, and cyanogenic potential in cassava. Ten genotypes from five different sources were used in a randomized complete block design with three replications, and data were repeatedly measured at three month intervals up to 15 months after planting. The mixed model analysis indicated significant ($p < 0.001$) differences among genotypes at each elevation for dry matter production. Significant interaction between plant age and source and between genotypes within source and plant age at all elevations indicated genotypic differences among sources as well as among genotypes within sources in production and partitioning of assimilates. The study indicated that dry matter content was higher at high altitude than at low and mid altitude. Highly significant ($p < 0.001$) differences for CNP were also observed between sources and among genotypes within source at mid altitude. Plant age effect was significant for CNP. Significant ($p < 0.001$) interactions between plant age with source and with genotypes nested within source indicated that genotypes as well sources produced different amount of CNP during plant growth cycle, obtaining high levels at all elevations at around six months after planting. The study also showed that starch and sugar contents were high at higher altitude than at low and mid altitude. A similar trend was observed with dry matter content.

Introduction

Cassava (*Manihot esculenta* Crantz) provides the livelihood of up to 500 million farmers and countless processors and traders around the world (FAO, 2001). It is a basic staple for hundreds of millions of people in the tropical and subtropical belt, as well as being a feedstock for numerous industrial applications, including food, feed and starch. The wide adoption of cassava in Africa has been due to its suitability and adaptation to the traditional farming and food systems, and the social circumstances of farming communities. It yields more calories of food per unit of labor effort than any other crops. A major limitation to cassava use is the toxicity from the cyanide compounds found in the fresh root. The cyanide is concentrated in or near the skin of the root, and is rendered free when the skin or root is broken. The cyanide content, however, varies with species, and changes under environmental conditions, such as humidity, temperatures, and plant age (Ozerol, 1984). Dry matter and starch content percentage vary among genotypes (Simwambana, 1988) and is determined by availability of moisture and light within a range of temperatures (Connor *et al.*, 1981). Dry matter is believed to be correlated with starch content, and is genetically highly stable over a range of environmental conditions (CIAT, 1984). Akparobi (1992) reported from screen house experiments that total dry matter was reduced at low temperatures, however, Cock (1985) and Kawano *et al.* (1987) reported higher dry matter content in storage roots at high

altitude than at low altitude. Genetic control mechanism and environmental influence on the important cassava characteristics are not clearly known. Carter *et al.* (1986) reported that 19% of the total cassava in Africa is found in mid altitude where trends in socioeconomic and physical environment favor increased production while earlier research work focused on the lower altitudes of tropics where cassava finds its most suitable growth environments (IITA, 1993; FAO, 1996). Ntawuruhunga (2000) reported a comparative study on cassava performance at three different altitudes. As cassava is being expanded into marginal high land-altitude where it was normally not adapted, it is then imperative to study and evaluate its performance in the new environment. This paper is reporting results of the effect of altitude on cyanogenic potential (CNP), dry matter, starch and sugar content production of cassava storage roots.

Materials and methods

Ten cassava genotypes from five different sources (Nyarukuhi, Nyarubekane, Migyera, SS4, Eala 07, Kiryumukwe/Serere, TMS 81/01365, TMS I92/0057, TMS I92/0067 and TMS I 91/0397) were planted at three different altitudes in Uganda. Field experiments were conducted at Bulisa, low-altitude (02° 02' N latitude, 31° 25' E longitude, 650 m a.s.l.), Namulonge, mid-altitude (0° 32' N latitude, 32° 53' E longitude, 1250 m a.s.l.) and at Kapchorwa high-altitude (01° 24' N latitude, 34° 27' E longitude, 1750 m a.s.l.) in Uganda during 1997/98 and 1998/99 growing seasons. A randomized complete block design replicated three times was used at each location. Data were recorded on three months basis using a destructive sampling method. Storage roots were sampled in the field according to Bokanga (1994) and analyzed for CNP. Root parenchyma samples were homogenized in 0.1M-orthophosphoric acid (50 g of storage roots tissues per 160 ml acid), the homogenate was centrifuged at 6,000 rpm for 15 minutes and the supernatant solution was used for

analysis. CNP was determined as described by Essers *et al.* (1993). Ethanol (95%) was used to extract the sugars from starch in a sample of cassava flour. The sugars were quantified colorimetrically using phenol and sulfuric acid and the residue was hydrolyzed with perchloric acid into monosaccharides (Dubois *et al.*, 1956). The sugars obtained were converted into starch by multiple factor of 0.9. The results were expressed in mg of free sugar or starch per 100 g of cassava flour of sample. Dry matter content (%) was determined by the oven method at 85 °C according to Kawano *et al.* (1987) and included the peel of the storage roots. Storage roots dry matter content, sugar content, starch content, and cyanogenic potential were subjected to analysis of variance at each time of observation. Finally mixed model analysis for repeated measurement over time using SAS (SAS, 1990) were used to determine the effect of time on the cassava attributes in the three environments.

Results and discussions

Dry matter production and partitioning.

Results of analysis of dry matter content of storage root (Table 1) show significant ($P < 0.001$) differences among sources at each location. There was a significant difference ($P < 0.001$) between genotypes within sources at mid altitude and high altitude. The interactions of plant age x source and genotype within source x plant age were significant ($P < 0.001$) at all altitudes indicating genotypic differences among sources as well among genotypes within source for dry matter production.

Figure 1 shows effects of location (altitude) and plant age on dry matter variation in cassava genotypes. Dry matter increased between 6 and 12 MAP for all genotypes at all altitudes. On average, the increase was 8.4% from 28.1 to 36.5%. However, this increase continued at low altitude and high altitude between 12 and 15 MAP while it decreased in the mid altitude due to the use of storage root reserves after a spell dry season

(CIAT, 1984). Tan and Cock (1979) reported that dry matter in storage roots represents the surplus of dry matter after the plant has met the requirements for the production of new leaves, maintenance of exiting leaves, and development and maintenance of tissues in stems and branches.

The high altitude (Kapchorwa) location resulted in higher dry matter accumulation than low and mid altitude locations. Cock (1987) reported similar results from trials conducted in Colombia indicating that storage root dry matter is usually greatest when temperatures are low. Kawano *et al.* (1987)

Table 1: Analysis of fixed effects of dry matter content of cassava grown at low, mid and high altitude in 1997/1998 season.

Source	Probability (level of significance)				
	ndf	ndd	Dmc		
			Low altitude	mid altitude	High altitude
Source	3	78	0.041	0.006	0.006
Genotype(source)	4	78	0.064	0.010	0.009
Time	4	78	0.001	0.001	0.001
Source x time	12	78	0.001	0.001	0.001
Genotype (source) x time	16	78	0.001	0.001	0.001
-2 Res Log Likelihood			479.67	590.99	590.90
CV (%)			13.71	16.84	15.92

Ndf: numerator of degree of freedom; ddf: denominator of degree of freedom; dmc: dry matter content.

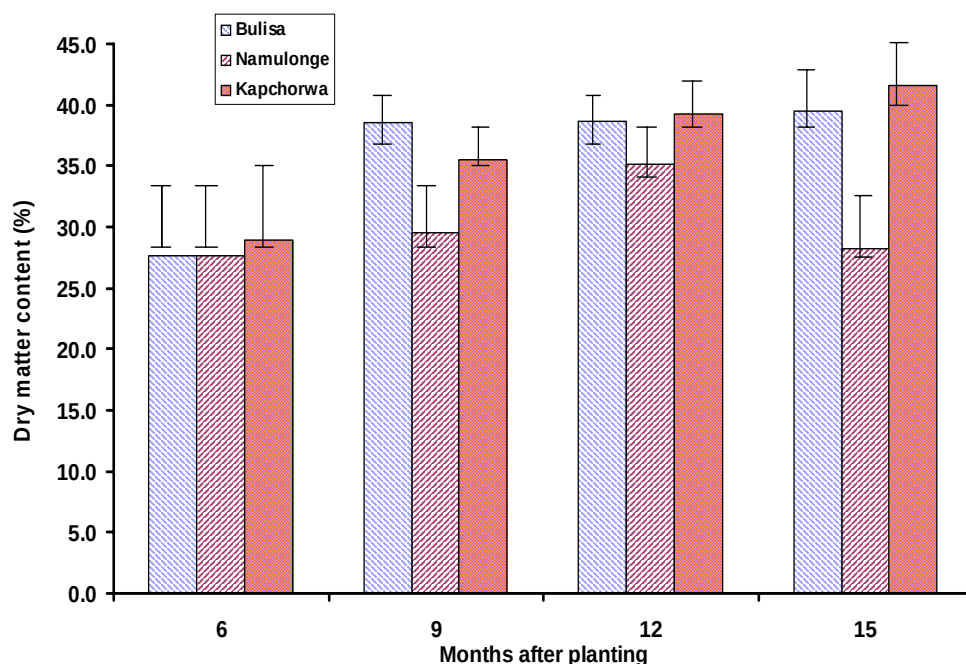


Figure 1: Effect of altitude and plant age on storage root dry matter production.

observed higher root dry matter percentage in 8-month-old plants harvested at the beginning of the dry season at a high altitude location than from plants 12 months old harvested at the beginning of the wet season at a low altitude location, indicating also a seasonal effect in storage root dry matter content. Based on this observation one could deduce from the present results that the cassava plant requires more dry matter for production and maintenance of its above ground biomass at low and mid altitudes than at high altitude, but this necessitates better physiological explanation. In potato production, cool night air temperatures are important because they affect the accumulation of carbohydrates and dry matter content in the tubers. Tubers initiation is reduced substantially if night air is above 20 °C and inhibited above 30°C (Schaupmeyer, 1997).

Figure 2 shows the location effect on dry matter distribution in different plant parts. The storage root accumulated more dry weight followed by stem and then leaves across locations. IITA (1990) also reported that the allocation of dry matter to storage root varied from almost none during the early growth

stage to as much as 80% of the daily dry matter production during the latter growth stage. At high altitude, genotypes allocated significantly ($P < 0.01$) lower dry yield to stems than at low and mid altitudes. Dry yield (fresh yield multiplied by dry matter content) allocated to leaves was much higher at mid altitude compared to low and high altitudes. At low altitude, genotypes allocated more dry matter to storage roots than at mid and high altitudes suggesting the suitability of cassava production at low altitude. TMS I 91/0057 and Nyarubekane were the best in allocating much higher dry matter yield to storage roots at low altitude, Migyera and TMS 81/01635 at mid altitude while TMS I 91/0397 and TMS 81/01635 were best at high altitude. Genotype Eala 07 produced low dry matter and distributed this equally in all plant parts at mid altitude and low altitude. Nyarubekane and Nyarukuhi produced no yield at high altitude because of their failure to sprout in this environment.

Cyanogenic potential in storage root. The results for analysis of cyanogenic potential (CNP) in storage root indicated highly significant ($P < 0.001$) differences between

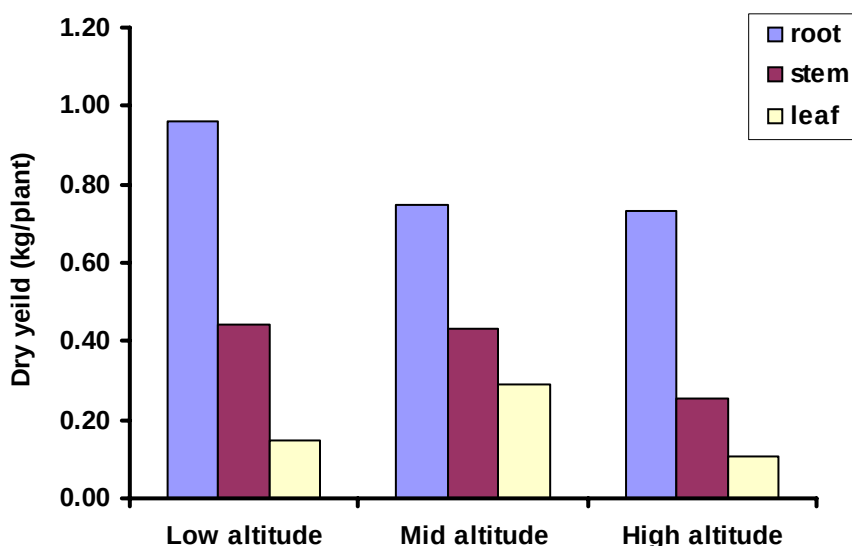


Figure 2: Effect of altitude on dry matter partitioning into storage root, stem and leaf of genotypes grown at Bulisa, Namulonge and Kapchorea in 1997/1998.

sources and between genotypes within sources at mid altitude (Table 2). Bokanga (1994) reported variations in CNP among genotypes adding that, they were larger in storage root than leaves.

Plant age effect was also significant ($P < 0.001$). There were significant ($P < 0.05$) interactions between plant age with source and with genotypes nested within source indicating that genotypes as well as sources produced different amount of CNP during the growth cycle. At low altitude, the results indicated significant ($P < 0.01$) variations and interactions were the same as at mid altitude. Genotypes within sources as well as sources effects at high altitude were significant ($P < 0.001$), but no significant interaction component was observed indicating that differences among genotypes and sources did not change over the growth period. Bokanga *et al.* (1994) and Githunguri *et al.* (2000) reported plant age, location and year effect on CNP, but no altitude effect was reported.

Figure 3(a) shows variation in CNP production by each genotype at each location. Eala 07 had the highest CNP and cyanogenic yield at low and mid-altitudes while the genotype Serere was the highest at high altitude. TMS 81/01635, TMS I 92/0057 and TMS I 92/0067, TMS I 91/0397 of the source 4 and source 5 respectively produced relatively low cyanogenic potential in their storage root

across locations. Overall, CNP production was much significantly higher at high altitude than at low and midaltitude locations. The trend was similar to that of the storage root dry matter content.

Figure 4 shows the effect of altitude and plant age on cyanogenic potential and cyanogenic yield. There was variation during plant growth in storage root CNP among genotypes at the 3 locations. High levels of CNP were observed at all locations at 6 MAP. There was again a decrease in CNP at all locations at approximately 9 and 15 MAP following short dry spells. Anthony and Lisbeth (1994) reported that cyanogenic glycoside concentration in the root increases until 6 MAP, remains stable until the 14 MAP and decreases, and thereafter increases. This high CNP coincided with the vegetative growth phases when leaf formation was important and the plant had a high leaf area (Bokanga *et al.*, 1994).

The CNP trend seems to follow a pattern similar to crop growth rate, which is mostly determined by rainfall (Bokanga *et al.*, 1994). The high altitude had a high level of CNP, followed by mid altitude and then low altitude in the early stages of growth up to 12 MAP. This suggests that if cassava growing is going to be promoted in high altitudes, it is advisable to introduce genotypes with a very low level of CNP. The same order of ranking was

Table 2: Mixed model analysis of fixed effects for cyanogenic potential (CNP) of genotypes grown at low, mid and high altitudes during 1997/1998 season.

Source of variation	Probability				
	ndf	ddf	Low altitude	mid altitude	High altitude
Source	3	78	0.001	0.001	0.001
Genotype(source)	4	78	0.001	0.001	0.001
Time	4	78	0.001	0.001	0.001
Source x time	12	78	0.022	0.022	0.158
Genotype (source) x time	16	78	0.003	0.003	0.055
-2 Res Log Likelihood			1254.7	1254.6	891.30
CV (%)			65.10	66.12	67.78

ndf: Numerator of degree of freedom; ddf: Denominator of degree of freedom.

maintained for the CN yield up to 9 MAP. CN yield increased throughout the growth cycle at low altitude, following the increase in storage root yield. It decreased after 12 MAP at mid and high altitudes but not at low. Bokanga *et al.* (1994) observed similar trend of cyanogenic yield. As storage root growth became the dominant sink (Ekanayake, 1993),

CNP levels dropped, but the total cyanogenic yield continued to increase.

Sugar and starch content. The sugar content increased from 6 MAP in all genotypes and decreased at 9 MAP except for genotypes Nyarukuhi, Eala 07, and Serere whose sugar contents continued to increase. With

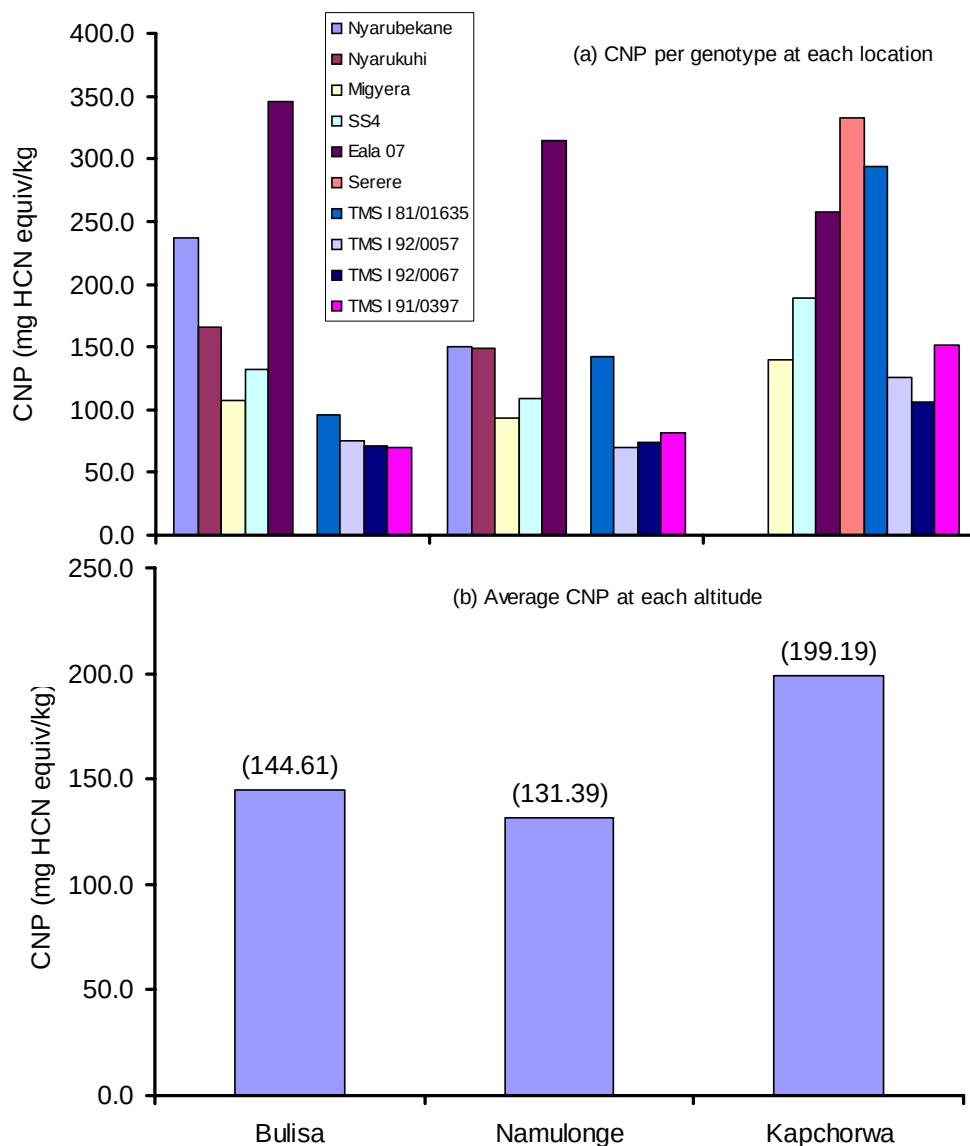


Figure 3: Cyanogenic potential in storage root per genotypes (a) and per location (b) of ten cassava genotypes grown at Bulisa, Namulonge, and Kapchorwa in 1997/1998 season.

increased growth, starch content showed an increasing trend in all genotypes. Figure 6 shows the effect of altitude on sugar and starch content in storage roots. Githunguri *et al.* (2000) reported that genotype and plant age had a significant effect on sugar content but not the zone and cropping system. Though lowest at high altitude before 10 MAP, the starch content increased and became higher than at mid and low altitudes. Sugar content was relatively higher at high altitude than at mid and low altitudes. The present

results suggest that starch and sugar contents tend to be higher at high altitude than at low and mid altitudes, an observation similar to that found for dry matter content in this study. This seems to confirm the reports that starch content is a genetic characteristic almost parallel with dry matter content, and the two are highly correlated (CIAT, 1984; Kawano *et al.*, 1987). However, the reason why dry matter or starch content in storage roots is higher at the high altitude than at low and mid altitudes could be that cassava plant tends to use more

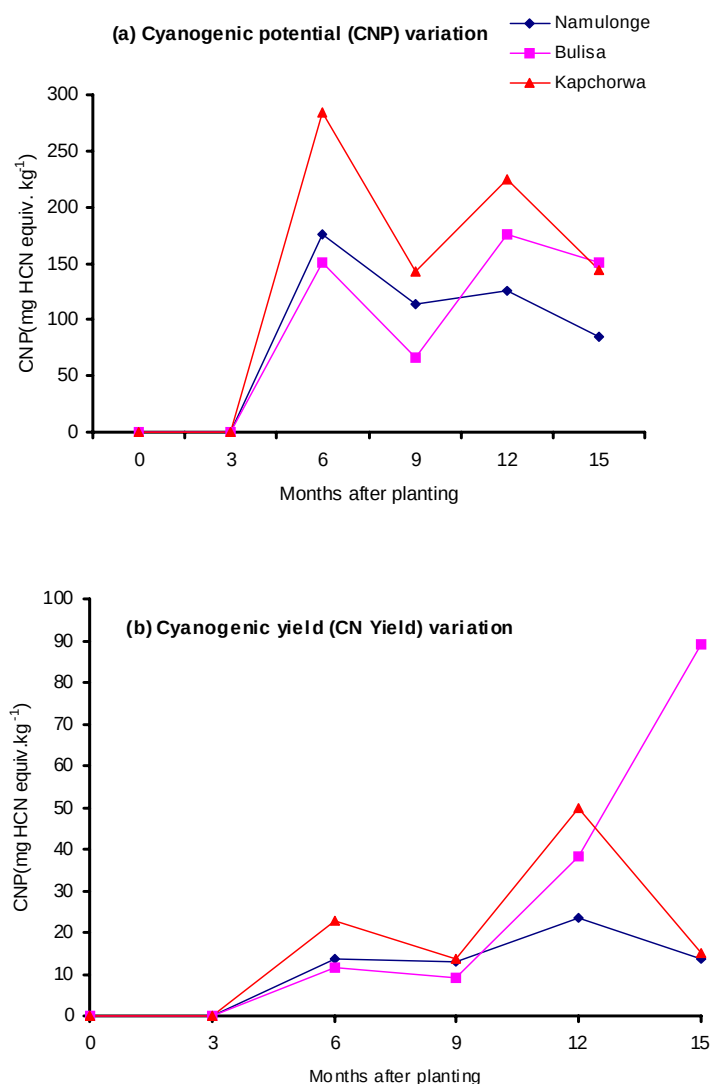


Figure 4: Effects of altitude and plant age on cyanogenic potential (a) and cyanogenic yield (b) in storage root of ten cassava genotypes grown at Bulisa, Namulonge, and Kapchorwa.

energy at high temperature to attain its performance than at low temperature but needs further investigation. In conclusion, the present study confirmed that the three cassava attributes investigated change with plant age and with environment. Specifically it has showed that cyanogenic potential is high at high altitude, and that storage root dry matter and sugar content increases with altitude.

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Towards the control of a severe form of cassava mosaic disease in Nigeria: diagnostic survey for cassava mosaic begomoviruses

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Abstract. A diagnostic survey was conducted in the southern states of Nigeria to determine if the Ugandan strain of *East African cassava mosaic virus* (EACMV-UG2) has spread to Nigeria. Farmers' fields (290) were visited in which 946 cassava leaf samples were collected in addition to 220 samples of whitefly vectors. The overall impression of cassava mosaic disease (CMD) symptom severity was recorded as mild, moderately severe or severe. Polymerase chain reaction (PCR) tests were conducted on the samples using nucleotide primers for the detection of *African cassava mosaic virus* (ACMV), *East African cassava mosaic virus* (EACMV) and EACMV-Ug2. CMD symptoms in most farms in Abia, Cross River, Ebonyi, Ekiti and Imo States were either moderately severe or severe. About the same number of farms had moderately severe and severe symptoms in Ogun, Ondo, Osun and Oyo States. CMD symptoms were mild in most farms in Akwa Ibom, Anambra, Delta, Edo, Enugu and River States. ACMV is the dominant species, occurring singly in 62.2% of samples while EACMV alone was detected in 1.1%. Mixed infections by the two viruses occurred in 22.4% of samples and the remaining 14.3% tested negative to the primers. The two viruses were also detected in the whitefly vectors. Most of the plants doubly infected with ACMV and EACMV were characterised by severe symptoms. A higher proportion (49%) of farms with mixed infections were observed in the survey area compared to the

14.3% recorded in a previous survey conducted in 1998. Biological variants of ACMV were observed of which some induced very severe symptoms. EACMV-UG2 specific primers tested negative to all the samples. Although EACMV-UG2 may not occur in the area surveyed, virulent strains of ACMV and EACMV seemed to occur. The extremely severe symptoms induced by some isolates of ACMV and by the two viruses in mixed infections underscore the need to make available to farmers, desirable resistant cassava genotypes to sustain cassava production in Nigeria.

Introduction

Cassava mosaic disease (CMD) is prevalent in sub-Saharan Africa (Cours-Darne, 1968; Hahn *et al.*, 1980; Fargette *et al.*, 1988; Otim-Nape *et al.*, 1998) and it is the major disease of cassava in Nigeria. In Africa, the disease is caused by *African cassava mosaic virus* (ACMV), *East African cassava mosaic virus* (EACMV) (Bock and Woods, 1983; Hong *et al.*, 1993) and *South African cassava mosaic virus* (SACMV) (Berrie *et al.*, 1998). The viruses belong to the family *Geminiviridae* genus *Begomovirus* (Mayo and Pringle, 1998). ACMV was the only known virus in Nigeria until 1999 when EACMV was reported (Ogbe *et al.*, 1999). Yield losses due to CMD can be as high as 90% on susceptible cassava genotypes (Terry and Hahn, 1980).

An outbreak of a severe form of CMD occurred in Uganda in the 1990s, which led to very low cassava yields in that country. The severe form of the disease was caused by a virulent strain of EACMV known as the Ugandan variant (EACMV-UG2) (Zhou *et al.*, 1997; Pita *et al.*, 2001a). Extremely severe symptoms are induced when EACMV-UG2 and ACMV co-infect cassava (Harrison *et al.*, 1997). Recent reports confirmed the presence of EACMV-UG2 in the Democratic Republic of Congo (DRC) and Congo Republic and (Neuenschwander *et al.*, 2002), which indicate its movement towards West African countries where ACMV predominates. The occurrence of EACMV, however, had been reported in Cameroon, Nigeria, Togo, Ghana, Ivory Coast and Guinea (Fondong *et al.*, 1998; Winter, 1998; Ogbe *et al.*, 1999; Offei *et al.*, 1999; Pita *et al.*, 2001b). In a bid to protect cassava production in Nigeria, IITA initiated a project on pre-emptive management of the severe form of CMD due to virulent strains of the viruses. An aspect of this project is to provide a situation report on CMD and the various cassava mosaic begomoviruses associated with the disease through a diagnostic survey.

Materials and Methods

A diagnostic survey was conducted in 16 southern states out of the 36 states in the country between December 2002 and August 2003. The States are: Abia, Akwa Ibom, Anambra, Bayelsa, Cross River, Delta, Ebonyi, Edo, Ekiti, Enugu, Imo, Ogun, Ondo, Osun, Oyo and River. The survey routes were pre-determined using the road map of Nigeria and the routes were selected to cover as much area of each state as possible. Cassava leaf and whitefly-vector samples were collected at an interval of between 10 and 15 km. In each farm visited, the overall impression of symptom severity of CMD was recorded as mild, moderately severe or severe. 290 farmers' fields were visited in which 946 cassava leaf samples were collected. In addition, 220 samples of whitefly vectors were collected. Extraction of DNA from the leaf

samples was conducted as reported by Dellaporta *et al.* (1983) and polymerase chain reaction (PCR) tests were conducted (Zhou *et al.*, 1997) using the following nucleotide primers for the detection of ACMV, EACMV and EACMV-UG2:

ACMV primers: ACMV-AL1/F (GCG GAA TCC CTA ACA TTA TC) and ACMV-AR0/R (GCT CGT ATG TAT CCT CTA AGG CCT G) (Zhou *et al.*, 1997); EACMV primers: UV-AL3/F (TAC ACA TGC CTC RAA TCC TG) and UV-AL1/R2 (CTC CGC CAC AAA CTT ACG TT) (Zhou *et al.*, 1997); EACMV-UG2 primers: UV-AL1/F1 (TGT CTT CTG GGA CTT GTG TG) and ACMV-CP/R3 (TGC CTC CTG ATG ATT ATA TGT C) (Harrison *et al.*, 1997). EACMV-UG2 DNA was used as positive control. Dr James Legg of IITA, Uganda supplied the DNA sample under permission of the Nigerian Plant Quarantine, Moore Plantation, Ibadan, Nigeria.

Results and Discussion

CMD symptoms were either moderately severe or severe in most farms in Abia, Cross River, Ebonyi, Ekiti and Imo States (Table 1). The number of farms with either moderately severe or severe symptoms was about the same as the number of farms with mild symptoms in Ogun, Ondo, Osun, Oyo and River States. CMD symptoms were mild in most farms in Akwa Ibom, Anambra, Delta, Edo and Enugu States. Only three farms were visited in Bayelsa State and CMD in them was mild

ACMV was the dominant virus species, occurring singly in 62.2% of the 946 samples tested while EACMV was detected in 1.1%. Mixed infections by the two viruses occurred in 22.4% of samples and the remaining 13.9% of the samples tested negative to the primers. Ogbe (2001) reported a similar trend and mixed infections of the two viruses have also been reported (Harrison *et al.*, 1997; Fondong *et al.*, 2000; Pita *et al.*, 2001a). Most of the samples that tested negative to the three primers used were collected from asymptomatic plants while a few samples were

from plants showing symptoms. Between 20% and 42% of plants sampled in Anambra, Cross River, Ebonyi, Enugu, Imo, Ondo and Osun States had mixed infections (Table 2) while

other states recorded less than 20% of plants doubly infected by the two viruses. The lowest proportion of plants with mixed infections occurred in Edo State (9.8%). The

Table 1: The status of cassava mosaic disease severity in farmers' fields in the southern states of Nigeria as determined by a diagnostic survey for cassava mosaic begomoviruses.

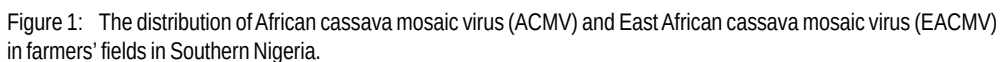
State	No. of farms	CMD severity		
		Mild (%)	Moderately severe (%)	Severe (%)
Abia	17	13.5	35.3	41.2
Akwa Ibom	11	63.6	36.4	0.0
Anambra	9	88.9	11.1	0.0
Bayelsa	3	100	0.0	0.0
Cross River	21	28.6	57.1	14.3
Delta	23	82.6	17.4	0.0
Ebonyi	13	30.8	61.5	7.6
Edo	31	71.0	22.6	6.4
Ekiti	16	37.5	25.0	37.5
Enugu	14	78.6	7.1	14.3
Imo	23	26.1	52.2	21.7
Ogun	31	54.8	22.6	22.6
Ondo	17	47.1	35.3	17.6
Osun	23	56.5	21.7	21.7
Oyo	30	50.0	43.3	6.7
River	8	50.0	37.5	12.5

Table 2: The proportion of cassava plants in farmers' fields infected by *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) as determined by a diagnostic survey in Southern States of Nigeria.

State	Plants infected by ACMV (%)	Plants infected by ACMV+EACMV (%)
Abia	75.0	16.7
Akwa Ibom	72.7	15.1
Anambra	64.0	28.0
Bayelsa	87.5	0.0
Cross River	64.7	25.0
Delta	70.0	14.3
Ebonyi	63.4	19.5
Edo	71.9	9.8
Ekiti	61.2	17.9
Enugu	47.8	40.9
Imo	49.4	42.3
Ogun	56.9	17.4
Ondo	43.7	39.1
Osun	54.9	32.4
Oyo	70.5	11.6
River	79.2	12.5

mixed infections are presented in Figure 3. The six cassava leaf samples in lanes 1–6 and 11–16 (Figure 3a) tested positive to both viruses. The EACMV primers also detected the DNA of EACMV-UG2 that was used as positive control. However, the EACMV-Ug2 was differentiated from the Nigerian isolates of EACMV by the EACMV-UG2 specific primers (Figure 3b). This implies that the virulent Ugandan variant (EACMV-UG2) might not be present in the part of Nigerian surveyed. This corroborates earlier report by Ogbe (2001).

ACMV was also the most frequently detected virus in the samples from



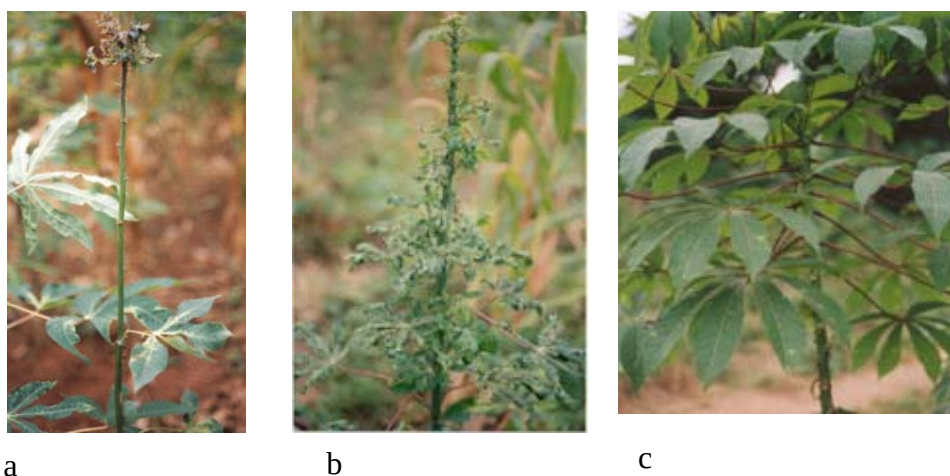


Figure 2: Cassava plants (a, b) showing severe symptoms of cassava mosaic disease due to mixed infections by *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) and a plant (c) that is symptom-free.

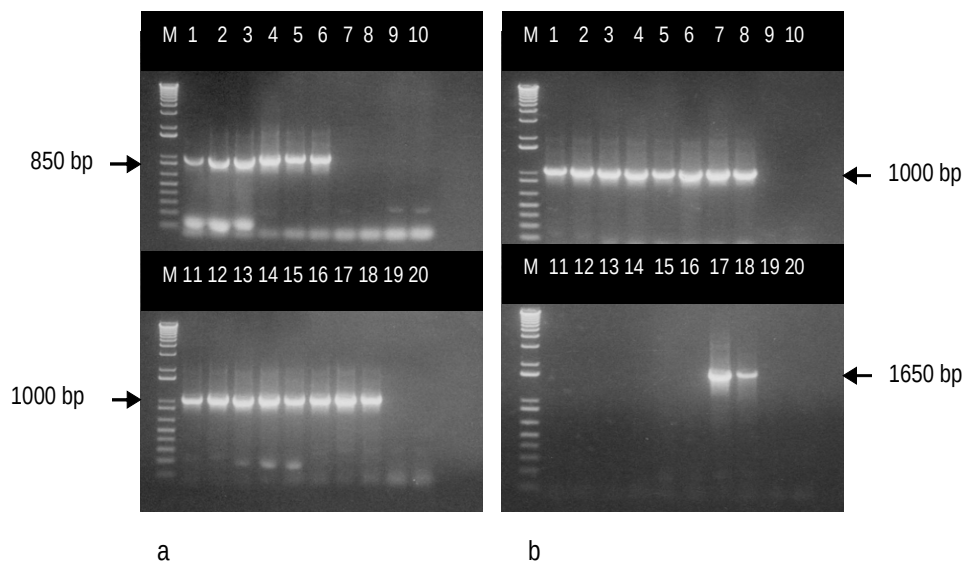


Figure 3: African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV) DNA fragments amplified by polymerase chain reaction and analysed by gel electrophoresis¹

¹ The viruses doubly infected cassava plants in farmers' fields in the Southern States of Nigeria.

M=1kb plus marker; lanes 1–6 contained the DNA of cassava leaf samples 75, 242, 503, 507, 647, 796, respectively; lanes 7 and 8 contained the DNA of virulent Ugandan strain of *East African cassava mosaic virus* (EACMV-Ug2) as positive control; lane 9 contained DNA of healthy cassava leaf as negative control; lane 10 contained DNA extraction buffer as negative control. This arrangement was repeated for lanes 11–16; 17 and 18; 19, 20, respectively.

Figure 3a, lanes 1–10 was tested by ACMV primers ACMV-AL1/F/AR0/R; lanes 11–20 were tested by EACMV primers UV-AL3/F/AL1/R2. Figure 3b, lanes 1–10 were tested by EACMV primers UV-AL3/F/AL1/R2; lanes 11–20 were tested by EACMV-Ug2 primers UV-AL1/F1/ACMV-CP/R3.

asymptomatic plants followed by mixed infections of ACMV and EACMV (Table 3). Only two asymptomatic samples contained EACMV alone. Most asymptomatic samples in Cross River, Delta, Edo, Ekiti, Ogun, Osun and Oyo States were virus-free suggesting that most visually healthy plants in those states were actually healthy. In contrast, most samples from asymptomatic plants in Abia, Ebonyi, Enugu and Imo States were infected with either ACMV or EACMV. This could be a reflection of the CMD pressure, which might be higher in these states than in Cross River, Delta, Edo, Ekiti, Ogun, Osun and Oyo. It could also imply that more resistant cassava genotypes are cultivated in Cross River, Delta, Edo, Ekiti, Ogun and Oyo. It was observed during the survey that most cassava fields in Cross River, Delta, Edo, Ekiti, Oyo, Ogun and Osun States contained moderately resistant (TMS 30572, TMS 30555) and resistant (TME 1) genotypes. The detection of ACMV and EACMV in asymptomatic plants (Table 3) is important information in the determination of

CMD incidence. It implies that CMD incidence is often underestimated.

A higher proportion (49%) of farms with mixed infections were observed in the survey area as against the 14.3% recorded in a previous survey conducted in 1998 (Ogbe, 2001). More farms and more plants per farm were sampled in the 2003 survey than in the 1998 survey in order to increase the chances of detecting EACMV-UG2, which was the object of the survey. This might partly accounted for the higher number of farms with mixed infections in 2003 than in 1998. Intensive farming and the dissemination of the viruses by whitefly-vectors could also bring about the higher frequency of farms with mixed infections. The two viruses were detected in the whitefly-vectors and at a high frequency in Enugu and Imo States where the highest number (40–42%) of plants with mixed infections was observed.

Two biological variants of ACMV were distinguishable based on symptoms induced on the same cassava genotype in the same

Table 3: Detection of *African cassava mosaic virus* (ACMV) and *East African cassava mosaic virus* (EACMV) in asymptomatic cassava plants in the Southern States of Nigeria.

State	No. of plants	Number of samples testing positive to:			
		ACMV	EACMV	ACMV +EACMV	No. of virus-free plants ¹
Abia	13	9	–	1	3 (23.1)
Akwa Ibom	7	3	–	–	4 (57.1)
Anambra	5	2	–	1	2 (40.0)
Bayelsa	1	–	–	–	1 (100)
Cross River	9	2	–	–	7 (77.8)
Delta	15	6	–	–	9 (60.0)
Ebonyi	10	7	–	–	3 (30.0)
Edo	15	2	–	–	13 (86.7)
Ekiti	11	1	–	–	10 (90.9)
Enugu	12	4	–	5	3 (25.0)
Imo	13	8	–	1	4 (30.8)
Ogun	24	2	–	–	22 (91.7)
Ondo	4	2	1	–	1 (25.0)
Osun	11	2	1	–	8 (72.7)
Oyo	18	3	–	–	15 (83.3)
River	4	2	–	–	2 (50.0)

¹ Numbers in parenthesis are percentages.

field. One variant induced a yellow and green mosaic pattern with mild leaf distortion while another variant induced a combination of a bleaching effect and green coloration with notable leaf distortion (Figure 4). Both variants were widely distributed and in some instances occurred in mixed infections leading to severe symptoms. Ogbe *et al.* (2003) had earlier reported the occurrence of biological variants of ACMV on a test plant *Nicotiana benthamiana* Domin and also serological variants of the virus. There are indications of the occurrence of strains/variants of cassava begomoviruses in the survey area. There were

some ACMV isolates that reacted differently to the different ACMV primers tested (Table 4). There were also some isolates that could not be identified by primers that detect ACMV, EACMV, *Indian cassava mosaic virus* (ICMV) and *South African cassava mosaic virus* (SACMV). The isolates also did not react with a pair of universal primers that could detect whitefly-transmitted geminiviruses of cassava, cowpea, okra and tomato. These isolates need to be characterised further and they could be novel strains of cassava mosaic begomoviruses. Genetic modification of species of geminiviruses has produced new

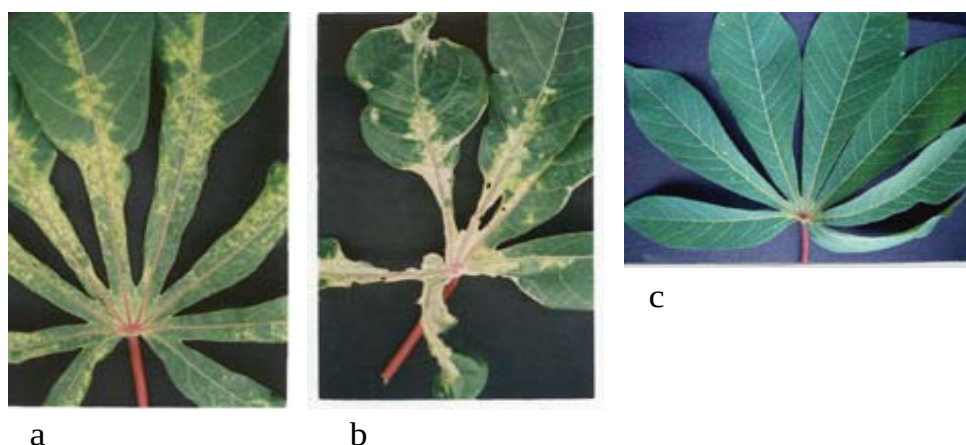


Figure 4: Characteristic symptoms of biological variants of *African cassava mosaic virus* on cassava leaf: yellow and green mosaic pattern with mild leaf distortion (a), combination of bleaching effect and green coloration with notable leaf distortion (b), symptom-free leaf (c).

Table 4: Representative reactions of variants of cassava begomoviruses in cassava leaves collected from farmers' fields in the Southern States of Nigeria.

Primer	Target virus	Infected cassava leaf sample number			
		389 (3)	422 (4)	605 (3)	706 (3)
ACMV-AL1/AR0/R	African cassava mosaic virus (ACMV)	+	–	–	–
JSP001/002	ACMV	+	–	+	–
UV-AL3/F/AL1/R2	East African cassava mosaic virus	–	–	–	–
ICMV/F/R	Indian cassava mosaic virus	–	–	–	–
SACMVCP3/CP	South African cassava mosaic virus	–	–	–	–
UNIVERSAL A/B ¹	Whitefly-transmitted geminivirus	+	+	+	–

¹ The primers detect whitefly-transmitted geminiviruses of cassava, cowpea, okra and tomato.

The numbers in parentheses are the symptom severity scores based on a 5-point scale (1 being no symptoms and 5 being severe mosaic and distortion of entire leaf (Terry, 1975).

species and strains such as EACMV-UG2 (Zhou *et al.*, 1997) and SACMV (Berrie *et al.*, 1998).

Conclusion

Between 43% and 76% of farms visited in 10 of the 16 states had CMD ratings of either moderately severe or severe. This is an indication that in the southern states of Nigeria where most of the crop is cultivated an epidemic of CMD could occur if resistant genotypes are not widely cultivated. It is, however, worthy of note that the Nigerian farmers practise the cultivation of mixtures of resistant and susceptible genotypes to forestall the entire farm being devastated by CMD. This possibly explains why an epidemic of CMD has not occurred despite the high proportion of mixed infections and the occurrence of virulent variants of cassava mosaic begomovirus in the survey area. The challenge, therefore, is to reduce the number of susceptible cassava genotypes that are being cultivated by the farmers. The project on the pre-emptive management of a severe form of CMD is, therefore, timely to provide additional resistant cassava genotypes to the Nigerian farmers to forestall any outbreak of a virulent recombinant and to also minimise the impact of EACMV-Ug if it eventually spread to Nigeria.

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Production of amylose-free sweetpotato plants by RNAi

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Abstract. In sweetpotato roots (*Ipomoea batatas* (L.) Lam., cv. Kokei 14) 18 to 20 % of the starch is amylose and the other major component is amylopectin. Granule-bound starch synthase I (GBSSI) is one of the key enzymes which catalyzes the formation of amylose in starch granules, a linear α -(1,4)-D-glucan polymer, from ADP-glucose. In this study, sweetpotato plants were transformed to produce amylose-free starch by RNA interference (RNAi). The gene construct that encoded double stranded RNA (dsRNA) of *GBSSI* first exon was introduced into the sweetpotato genome by *Agrobacterium tumefaciens*-mediated transformation to inactivate the endogenous *GBSSI* gene. Starches from 80% of transgenic lines showed red-brown staining pattern by iodine staining, indicating a reduction of amylose content. Starches from these transgenic plants, which showed red-brown staining pattern were confirmed to be amylose-free by calculations from the blue value at 680 nm.

Introduction

Sweetpotato is one of the most important crops in the world and provides not only staple food but is also important as an industrial raw material. Genetic engineering of starch has great potential for the quality improvement of sweetpotato starch for the development of new food and industrial products. Amylose and amylopectin are the two main polysaccharide components of most natural starches. In sweetpotato plants, a relatively narrow range in amylase content (10 – 20 %) has been observed in comparison with

other crops (Noda *et al.*, 1998). Since an amylose-amylopectin ratio is an important factor influencing the textual properties of starch, a new sweetpotato variety that contains starch, which is amylose free or has low amylose content, would help develop new industrial applications.

The granule-bound starch synthase I (GBSSI) is one of the key enzymes in the biosynthesis of starch, which catalyzes the formation of amylose in starch granules, a linear α -(1,4)-D-glucan polymer, from ADP-glucose. Amylose-free or low amylose starch has been produced by the antisense *GBSSI* RNA technique in potato (Visser *et al.*, 1991, Kuipers *et al.*, 1994) and rice (Terada *et al.*, 2000). Recently, Kimura *et al.* (2001) introduced the sense *GBSSI* cDNA into the sweetpotato genome and obtained one transgenic plant with amylose-free starch form a total 26 transgenic plants. They revealed that co-suppression of endogenous *GBSSI* resulted in a reduction in the amount of amylose by sense suppression of the *GBSSI* gene in sweetpotato.

Recently, double stranded RNA-mediated gene silencing has been found to be an effective technology in the genetic improvement of crops as well as in functional genomic studies (Levin *et al.*, 2000). In this study, we introduced the construct that contains both sense and antisense of *GBSSI* fragments into sweetpotato plants to inactivate the endogenous *GBSSI* gene. Amylose-free transgenic sweetpotato were obtained efficiently by the double stranded RNA mediated technique in a higher frequency than by the co-suppression

technique in sweetpotato (Kimura *et al.*, 2001) or the antisense technique in potato (Visser *et al.*, 1991).

Materials and Methods

Plasmid construct. The gene-silencing constructs were cloned into the binary vector pCambia1300 (Medical Research Council Laboratory of Molecular Biology, Hills Road, Cambridge, England) as HindIII-EcoRI fragments, replacing the α -glucuronidase-containing HindIII-EcoRI region of pCambia. The pGBSSI-SIAS contains the sense orientation of GBSSI first exon, first intron and the antisense orientation of the first exon (Fig. 1).

Transformation. Embryogenic calli were induced from shoot meristems of sweetpotato, cultivar Kokei 14, on 4F1 medium, which is LS medium (Linsmaier and Skoog, 1965) containing 1 mg/l 4-fluorophenoxyacetic acid (4FA), 3% (w/v) sucrose and 0.32% (w/v) gellan gum (Otani and Shimada 1996). Transformation was performed according to the method of Otani *et al.* (1998).

Iodine staining of roots and measurement of amylose content. The sweetpotato roots, which grew for four months in the biohazard greenhouse, were washed, cut into pieces and stained at the surface of root slices with iodine solution (0.1 % I₂, 1 % KI). The starches were extracted from the roots and the amylose content calculated from the blue value at 680 nm according to the method by Noda *et al.* (1998). Via *Agrobacterium tumefaciens*-

mediated transformation the double stranded constructs pGBSSI-SIAS were integrated into the genome of the sweetpotato cultivar Kokei 14. Eighty-nine individual hygromycin-resistant plants were regenerated and grown in Wagner pots (1/5000 a) in the biohazard green house. After four months growth, the number of veins over 10 cm, total length of the veins, the number of root roots over 10 g and total length of the root roots were determined.

Results and Discussion

No morphological differences were observed between non-transgenic plant and the hygromycin resistant plants. Table 1 shows the results of a non-transgenic plant and 15 transgenic lines. Number and total length of veins and number and total of roots showed no significant differences between a non-transgenic plant and the transgenic plants, although individual differences were large.

The hygromycin resistant lines were investigated for starch character by iodine staining. Twelve transgenic lines of the 15 lines contained red-brown staining starch while the other three lines contained blue staining starch similar to the non-transgenic plant (Table 1). This shows that 80% of the transgenic plants have starches with no or low amylose and had been modified. Starches were isolated from roots of the 15 transgenic lines and the non-transgenic plant to examine their amylose contents. The twelve transgenic lines which were stained red-brown by iodine were under 0.166 of blue value, which is the blue value of amylopectin,

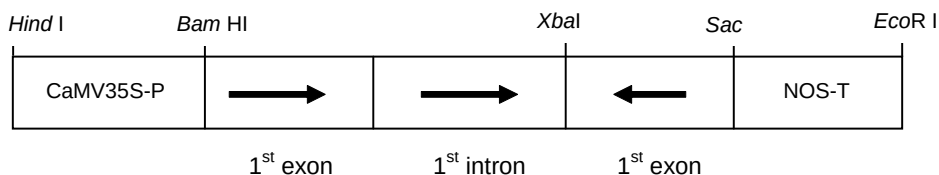


Figure 1: Composition of the double strand GBSSI construct containing the first intron between the first exon GBSSI in sense orientation and the first exon in antisense orientation.

Table 1: Characteristics of a non-transgenic Kokei 14 and the 15 lines of hygromycin resistant plants.

Strain	No. of vines per 10 cm	Total length of vines (cm)	No. of roots per 10 g	Total weight of roots (g)	Iodine staining pattern
Kokei 14	7	385.6	5	305.8	B ³
GR-01	5	406.4	7	237.4	R
-02	5	440.8	3	192.6	B
-03	4	347.9	2	179.7	R
-04	4	259.7	6	338.0	R
-05	6	336.9	9	299.3	R
-06	5	295.7	4	253.7	R
-07	4	244.8	4	252.1	B
-08	8	156.6	7	303.8	R
-09	7	378.0	6	324.9	B
-10	6	321.9	7	212.5	R
-11	4	410.1	6	222.4	R
-12	5	264.0	5	221.3	R
-13	5	209.0	2	328.9	R
-14	4	242.5	4	212.5	R
-15	5	323.2	4	248.0	R
Average					
T lines with amylose	5.3±1.5 ¹	354.5±100.1	4.3±1.5	254.8±50.9	B
T lines without amylose	5.1±1.2ns ²	297.8±75.8ns	5.3±2.1ns	256.5±66.3ns	R

¹Mean ± sd; ²T test; ³B: blue-black staining pattern, R: red-brown staining pattern.

indicating amylose free starch. The other three lines and non-transgenic Kokei-14 showed blue values of 0.350 to 0.362, and they, therefore, contained around 17 % amylose. The yield of the amylose-free roots showed no differences compared to the yield of roots having normal amylose content (Table 1).

The transgene was confirmed in all lines of the transgenic plants by Southern hybridization (data not shown), and the amylose-free lines did not express the *GBSSI* mRNA revealed by Northern analysis nor did they produce the *GBSSI* protein revealed by SDS-PAGE (data not shown). These results suggest that double stranded RNA inhibited the expression of *GBSSI* gene completely in 73.7 % of the transgenic plant lines. Kimura *et al.* (2000) obtained amylose-free sweetpotato by sense silencing at the frequency of 0.4 % (1/26). RNA interference

is an effective technology which may be used in the genetic improvement of crops.

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Yam production in Ghana: To stake or not to stake - A plant breeding perspective

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Abstract. Staking is the yam planter's main concern especially in the yam growing areas of Forest-Guinea Savannah Transition and Coastal Savannah of Ghana. Staking is not only laborious, but also very costly. The environmental degradation due to deforestation is also enormous. Various agronomic approaches such as the use of plastic mulch, varying length of stakes among others, have been recommended in the past to solve this problem. This paper presents a breeding perspective for solving the yam staking problem by assessing white yam (*D. rotundata*) and water yam (*D. alata*) genotypes under staking and non-staking conditions and discussing the environmental impact of staking.

Introduction

Staking is one of the yam-planter's main concerns (Degras, 1995). When yams are grown as a sole crop, yield is increased by staking by between 34 and 105% (Ndegwe *et al.*, 1990). An irregular response to staking has been found when yams are planted with other crops (Kole, 1995). Staking is not only laborious (20% of all work in yam production) but also very costly and scarce. Staking especially in the humid forest is carried out to help the twining yam stems display their leaves to attract adequate solar energy for efficient photosynthesis (Orkwor and Asadu, 1998). In the forest zone of Nigeria, for example, staking is needed for maintaining high leaf area duration (LAD) and the

associated high yield (Enyi, 1972b; Hahn and Hozyo, 1983). Staking also usually increases NAR (Enyi, 1973; Okigbo, 1973; Irvine, 1940). There are varietal differences in response to staking, whilst in *D. rotundata* it is almost a must if significant yields are to be obtained, *D. alata* yams are rarely staked (Degras, 1986), and *D. cayenensis-rotundata* are grown in many parts of Africa without artificial staking. Yam production is characterised by clearing of new areas on yearly basis. Yam is estimated to occupy about 6.32% of total cropped area of Ghana hence such a land area is deforested and in the long run degraded through yam cultivation each year. It is also projected that growth rate for yams in Ghana is 2.75% per annum (MTADP, 1990) and that expansion in cultivated area is expected to be the main source of growth, contributing to 80% of the overall growth. The projected growth rate in the area of cultivation is 2% per annum with productivity growth (yield) expected to contribute the remaining growth with a growth rate of 0.75% per annum (PPMED, 1995). Farmers indicate that clearing of new lands is done in part to obtain stakes for staking their yams (personal communication). Traditionally, farmers either adopt the parkland system of farming or leave it non-staked especially when large acreages are involved. Alternatively, other agronomic measures to reduce the number or size of stakes to be used per hectare are being practiced by farmers. It is therefore imperative that studies are conducted to identify genotypes capable of tolerating no staking

condition with little or no reduction in tuber yields. The objective of this paper therefore was to: discuss environmental impact of staking yams in Ghana, evaluate yam genotypes for high and stable yields with or without staking, and compare the performance of *D. rotundata* and *D. alata* under staking and non-staking conditions.

Materials and Methods

The experiment was conducted at 3 locations: Forest (Fumesua), Forest-Savannah transition (Wenchi) and Derived Savannah (Bawjiase) from 2000-2002 in Ghana. Two factors staking and genotypes were assessed. Staking had 2 levels: staking and non-staking and genotypes had 2 varieties: *D. rotundata* (60 testlines) and *D. alata* (73 testlines).

The experimental design used was Augmented RCB with 3 blocks and 3 replicated checks. Data was collected on the following parameters: pest and diseases (incidence and severity; scale of 1-5), weed biomass (12 weeks after sprouting- 5 weeks first weeding) and yield and its components. Quantitative data was analyzed using GLM and Mixed Models programmes of SAS, (1987) and qualitative data by SPSS Windows

version 10. The environmental impact of staking was projected using secondary data.

Result and Discussions

Table 1 shows the results of GLM analysis of *D. rotundata* genotypes at Fumesua in 3 locations in 2 years under staking and non-staking conditions. Significant locational differences were observed with respect to stand at harvest, leafspot severity, virus severity and yield of *D. rotundata* (Table 1). Non-staking significantly increased leafspot severity and subsequently reduced the yield of *D. rotundata* genotypes. Staking and testline interaction of *D. rotundata* also had significant effect on leafspot and yields of *D. rotundata*. Table 2 shows the results of GLM analysis of *D. alata* yam genotypes in 3 locations in 2 years under staking and non-staking conditions.

Effect of staking on pest and diseases occurrence on *Dioscorea* spp. Location and testlines significantly influenced anthracnose and virus severity as well as yield and single tuber weight of *D. alata* (Table 2). Staking, however, did not have any significant effect on yield and its components. The interaction

Table 1: Results of GLM analysis of *D. rotundata* genotypes in 3 locations in 2 years.

***Source	Stand at harvest		Leafspot severity		Virus severity		Yield t/ha	
	DF	MS	DF	MS	DF	MS	DF	MS
LOC	2	29.80**	2	5.34**	2	3.43*	2	403.05**
STAK	1	1.39	1	7.82**	1	0.67	1	214.86**
LOC*STAK	2	5.81	2	3.21*	2	0.32	2	55.25*
C	2	21.19*	2	0.61	2	0.38	2	28.98
LOC*C	6	7.14	6	0.84	6	0.19	6	30.57
X(C)	53	11.77	51	4.65*	51	0.34	51	139.82**
LOC*X(C)	93	6.28	90	5.64*	90	0.31	88	101.75**
YR*X(C)	48	10.73	45	4.47*	45	0.15	43	62.32*
YR*LOC*X(C)	27	5.46	12	3.64*	12	0.07	11	175.86**
STAK*X(C)	52	4.44	50	3.33*	50	0.23	50	67.23*
LOC*STAK*X(C)	89	4.52	69	0.53	69	0.30	69	93.59**
YR*STAK*X(C)	47	4.65	38	0.84	38	0.19	30	114.06**
YR*LOC*STAK*X(C)	22	5.86	0	.	0	.	1	63.76*

*** Loc, stak, c, x and yr refer to location, staking, checks, testlines and year respectively.

of staking and location was also not significant on all parameters measured (Figure 1). Most of the testlines of staked *D. rotundata* (73.3%) had no visible sign of leafspot while significantly low percentage (5.2%) of the non-staked testlines had no visible sign of the disease indicating a strong but negative association of non-staking and leafspot severity.

Anthraco severity had no significant effect on *D. alata* testlines (Figure 2). Most of the testlines (both staked and non-staked) had high frequencies of testlines with no visible signs of the disease.

Effect of staking on weed biomass. Weed infestation was significantly high in *D. rotundata* fields but not in *D. alata* fields. Most (58.8 and 77.4% for staked and non-staked respectively) of the *D. rotundata* genotypes had weed biomass of between 1.1-2.0kg/4m², while very few (between 4.3 and 2.5% of staked and non-staked) *D. alata* genotypes had weed biomass of 1.1-1.5kg/4m². This supposes that in *D. rotundata*, weed biomass had strong and positive association with staking (Figure 3).

The overall results of the *D. rotundata* testlines in the various locations show that

Table 2: Results of Generalized Linear Model analysis of *D. alata* in 3 locations in 2 years.

Source	DF	Mean square			
		Anthraco severity	Virus severity	Yieldt/ha	STWTkg
LOC	2	18.92**	15.7**	625.34**	15.87**
STAK	1	0.23	0.67	52.86	3.97
C	2	1.60**	12.6**	115.04**	4.6
X(C)	47	1.06**	4.27**	99.50**	11.95*
LOC*X(C)	86	0.75**	4.58**	29.16	1.17
YR*X(C)	41	0.76**	0.60*	66.49	1.4
YR*LOC*X(C)	33	0.77**	3.22**	27.66	1.36
STAK*X(C)	47	0.38	1.68	22.73	1.26
LOC*STAK*X(C)	84	0.29	0.16	18.00	0.65
YR*STAK*X(C)	40	0.51*	2.21**	23.57	1.45
YR*LOC*STAK*X(C)	28	0.62**	0.12	23.23	1.7

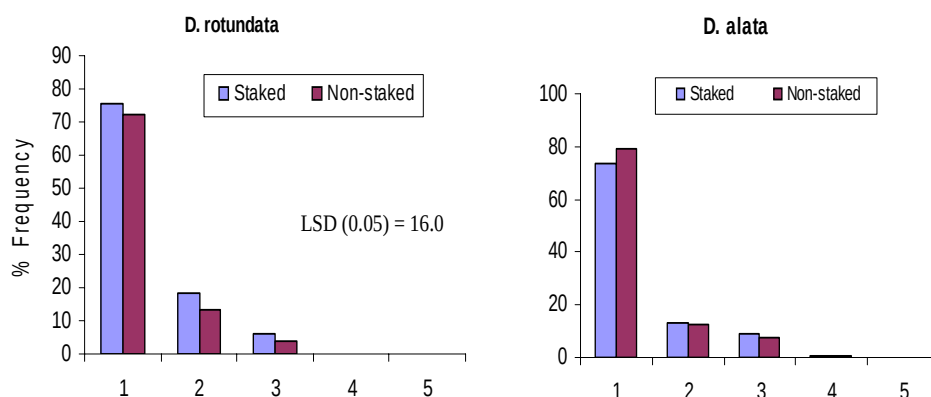


Figure 1: Effect of staking and non-staking on mean virus severity of *D. rotundata* and *D. alata* at 3 locations in 2 years.

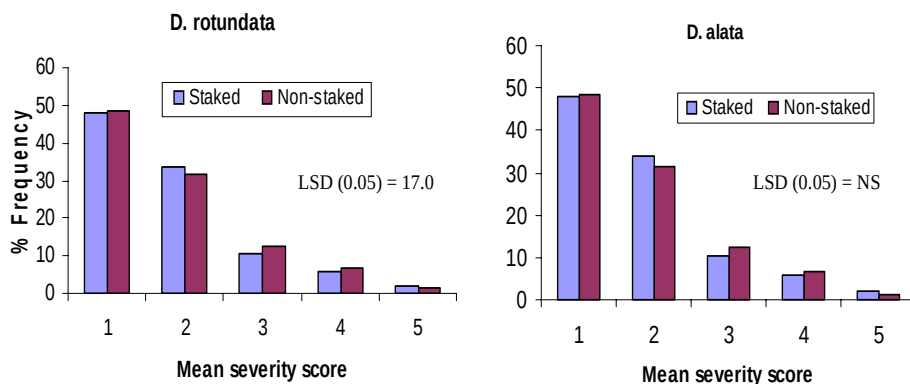


Figure 2: Effect of staking and non-staking on mean leaf spot disease (left) and anthracnose (right) severity of *D. rotundata* and *D. alata* at 3 locations in 2 years.

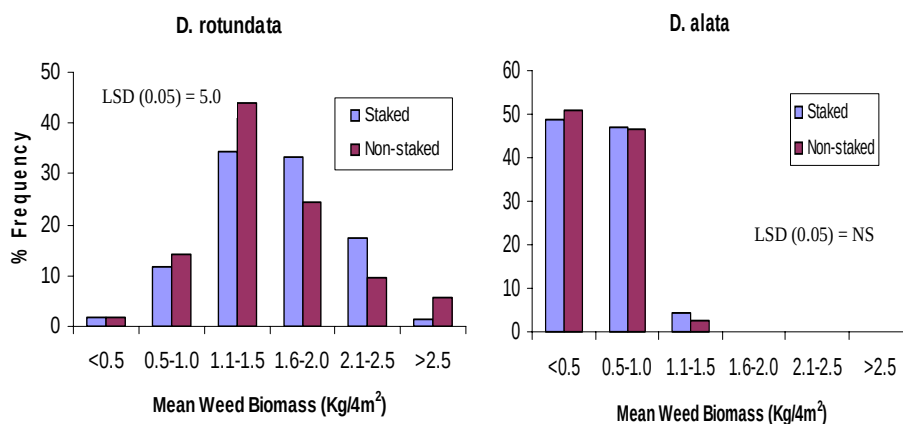


Figure 3: Effect of staking and non-staking on mean weed biomass at 12 weeks after sprouting (% weeks after first weeding) at 3 locations in 2 years on *D. rotundata* and *D. alata*.

testlines TDr95/19177, NKA2000/001 and Dorban proved adaptable in all 3 locations. This corresponded to low disease incidence and severity and low weed biomass confirming the assertion that both leafspot severity and weed biomass have strong but negative association with staking. Results of testlines Muchumudu, TDr89/02665, Tela, TDr96/01628 and KUP-2000/001 showed that to obtain the most performance, yams must

be staked. Some other genotypes exhibited specific adaptation to non-staked conditions at Bawjiase, Fumesua and Wenchi.

In *D. alata* most of the genotypes had low pest incidence including weeds and disease pressure even under non-staked conditions resulting in good yields even under non-staked conditions. None of the testlines needs staking to express its full potential.

Conclusions and Recommendations

D. alata genotypes do better under no-staking conditions than *D. rotundata* genotypes. Some *D. rotundata* genotypes can be grown under non-staking conditions with no significant yield loss. Leafspot incidence and severity and weed biomass have strong and positive association with non-staking and can significantly reduce yield of *D. rotundata*.

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Towards identifying the full set of genes involved in post-harvest physiological deterioration in cassava

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Abstract. Cassava is the world's sixth most important crop in terms of production and is a vital staple food to over 500 million in the humid tropics. Unfortunately, it suffers from a rapid post-harvest physiological deterioration (PPD) that can render the roots uneatable and unmarketable within 24-72 hours of harvest. Increased urbanization has lengthened the distance and time between farmers' fields and markets and processors, thereby incurring losses, wastage and discounting of poor quality cassava. PPD is a major constraint to the development of cassava for farmers, processors and consumers alike, and the successful application of strategic research is necessary to solve this problem. With a view to fully understanding PPD and to ultimately producing the tools to control this problem, we have identified some of the key genes that play major roles during PPD and mapped these on the genetic map of cassava. Recently, we have embarked on a major programme employing massively parallel methods of gene analysis (cDNA microarrays) to identify the full set of genes involved in PPD. Screening 11,136 cDNA clones from early and late PPD-related libraries using a series of character probes from a range of time points during the time course of deterioration has led to the identification of 114 clones whose expression is increased and 70 clones whose expression is decreased at least two-fold during PPD.

Introduction

Cassava (*Manihot esculenta* Crantz) is a starchy root crop whose centre of origin is on the south-western borders of the Amazonian basin but which is now cultivated extensively throughout the humid tropics where it provides the staple food for over 600 million (Cock, 1985). Upon harvesting the roots suffer from a rapid deterioration that can render them unpalatable and unmarketable within 24 – 72 hours, known as post-harvest physiological deterioration (PPD). PPD is a major constraint to the development of the crop from a village-based resource to a commodity also supplying urban populations and larger scale processing facilities (Wenham, 1995). The increased times and distances between field and consumer or processor lead to substantial discounting, wastage and added costs due to the effects of PPD. Urban consumers may turn to alternative, often imported, sources of starchy food, processors suffer from unreliable input material and quality control problems, and farmers suffer from loss of potential income. Therefore, research directed towards introducing resistance to PPD, or delaying the response, is considered a priority by international bodies such as the Food and Agriculture Organisation of the United Nations (FAO) and the Cassava Biotechnology Network.

PPD

is an abiotic response of the cassava root to the damage caused during the harvesting process and is not due to microbial action, though this does take place subsequently (reviewed in Beeching *et al.*, 1998). Visual symptoms of PPD in the storage root are blue-black discoloration of the vascular tissue, general blue fluorescence under UV light and blockage of the xylem by occlusions and tyloses that can be seen under the microscope. These changes are accompanied by an increase in respiration, the accumulation of a range of secondary metabolites, changes in enzyme activity, protein synthesis and gene expression. These data show that PPD is an active response of the root to harvesting with strong parallels to wound, oxidative stress and senescence responses. Genetic, biochemical and molecular aspects of the problem are now much better understood; for example, several important genes have been cloned and characterised, and the expression of one of these has been analysed in transgenic cassava (Beeching *et al.*, 1998; Beeching *et al.*, 2002).

Due to its high heterozygosity, a correlation between high dry matter content and PPD, and a complex genetic X environmental interaction, the conventional breeding of cassava for a reduced PPD response is problematic. However, biotechnology can be used to generate an in-depth understanding of PPD, provide molecular markers that could be used for marker assisted selection (MAS) in breeding programmes (Cortés *et al.*, 2002), and provide genetic tools to directly manipulate PPD. We have initiated a collaborative programme of research between the University of Bath, U.K., and CIAT, Colombia, to exploit massively parallel systems for the analysis of gene expression in order to identify the full set of genes that are involved in the PPD response. These data should provide valuable insights into the classes of genes involved in the response, and some of these genes themselves together with their promoters could provide gene tools with the potential of modulating the PPD response. While this

research programme is only at its halfway point, it has so far proved highly successful at identifying candidate genes. Here we present results on the cloning and screening process, and on the preliminary identification of candidate genes.

Materials and Methods

Plant material. Cassava cultivar CM 2177-2 was grown in the field at CIAT and roots were carefully harvested after about nine months growth.

Induction of PPD. Immediately after harvest proximal and distal ends of the storage roots were removed and two transverse V shaped cuts made along the length of the root. Exposed proximal and distal ends of the root were covered with Parafilm and roots were stored at ambient temperature. In our hands this system gives an even progression of PPD symptoms throughout the root.

Nucleic acid methods. For cDNA cloning, total RNA was extracted from storage roots according to Reilly *et al.* (2001), and messenger RNA (mRNA) purified with the PolyATtract system (Promega) according to the manufacturer's instruction. mRNA was used to synthesise cDNA and cloned into Lambda Zap II using Stratagene kits according to the manufacturer's instructions. Preparation of cDNA clones, microarray spotting and hybridisations were carried out according to the protocols on the Institute for Genome Research (TIGR) website (<http://www.tigr.org/tdb/microarray/>). cDNA clones were PCR amplified using T3 and T7 primers and the DNA spotted on to PL-100C-Poly L Lysine slides (CEL Associates) using a Hitachi SPBIO 1.55 robot. Each slide contained four technical replicates of the cDNA clones and four replicates of control genes and target spike genes. cDNA probes were synthesised from mRNA using a SMART cDNA synthesis kit (Clontech). For all experiments the earliest time point cDNA was labelled with Cy3 and the later with Cy5, thus up-regulated genes

appear red. Spike genes used were TIGRE1 – E5 (should appear yellow when probed with Cy3 plus Cy5), TIGRE6 and E7 (should appear green with Cy3 only) and TIGRE8 and E9 (should appear red with Cy5 only). Scanning of the hybridised slides was performed using a VersArray Chipreader (Biorad) and analysis of the hybridisations with ArrayVision (Amersham Biosciences). DNA sequencing was with an Applied Biosystems 3700 DNA Analyzer and 9600 Gold Block Thermal Cyclers. DNA preparation and sequencing reactions were prepared with MWG Biotech Roboprep 2500 and Roboseq 4200 robotic systems. All sequencing reactions were with Applied Biosystems' Big-Dye Terminators. BLAST searches to tentatively identify clones were carried out on the NCBI website (<http://www.ncbi.nlm.nih.gov/>) (Altschul *et al.*, 1997). Multiple alignments were made using CLUSTAL (Higgins *et al.*, 1996). All other molecular methods were standard (Sambrook, *et al.*, 1989).

Results

cDNA library construction and evaluation.

Messenger RNA was purified from mature roots of cassava cultivar CM 2177-2 over a post-harvest time course at 0, 6, 12, 24, 48 and 96 hours after harvesting. mRNA from time points 0, 6 and 12, and from 24, 48 and 96 hours was pooled separately and used to synthesise cDNA, which was directionally cloned into Lambda Zap II; thereby creating an "Early PPD" and a "Late PPD" cDNA libraries. These libraries were evaluated as to their size and quality. The "Early PPD" library contained 1.4×10^7 plaque-forming units (pfu) per ml, of which 11.2% were non-recombinants and at least 80% of the insert sizes were greater or equal to 0.9 kilobase pairs (kb) in size, and the "Late PPD" library contained 3.8×10^9 pfu/ml, of which 0.8% were non-recombinants and 70% were greater or equal to 0.9 kb.

cDNA microarray hybridisations. DNA PCR amplified from 7,680 clones of the "Early PPD"

library and 3,456 of the "Late PPD" library, a combined total of 11,136 clones, were spotted onto slides. Each slide contained four technical replicates of each clone together with four replicates of the control genes and target spike genes. These slides were hybridised with Cy3 and Cy5 labelled probe cDNA as in Table 1, the earlier probe was always labelled with Cy3 and the later one with Cy5; thus up-regulated clones should appear red and down-regulated green. These hybridisations proved highly successful.

Microarray data analysis. The hybridised slides were scanned using the VersArray Chipreader and the data analysed using ArrayVision software. Two criteria were used to identify clones for further analysis: one in which clones were flagged for each hybridisation, e.g. 0 vs. 12, 0 vs. 24 hours, etc.; and one involving analysis of data normalised across arrays. Only clones that showed up-regulation by at least a factor of two (2^1) or a down-regulation of at least 2.8 ($2^{1.5}$) in at least two array hybridisations were selected. The higher factor for the down-regulated clones was used due to the large number of clones that were down-regulated (green) in order to reduce these to a manageable number. These strict criteria should eliminate most false positives and not too many real positives. Using these methods,

Table 1: Outline of the microarray hybridisation experiments.

Experiment	Hybridisation	Probes
Time course experiments	Hybridisation 1	0 vs. 12 hours
	Hybridisation 2	0 vs. 24 hours
	Hybridisation 3	0 vs. 48 hours
	Hybridisation 4	0 vs. 72 hours
	Hybridisation 5	0 vs. 96 hours
Range experiments	Hybridisation 6	12 vs. 24 hours
	Hybridisation 7	24 vs. 48 hours
	Hybridisation 8	48 vs. 72 hours
	Hybridisation 9	72 vs. 96 hours

Hybridisations were carried out with Cy3 (the earlier time point) and Cy5 (the later time point) labelled cDNA probes to determine the time course and range of changes in gene expression in 11,136 PPD-related cDNA clones.

out of the total of 11,136 cDNA clones examined, 114 clones showing at least a two-fold increase in gene expression during PPD were identified together with 70 clones showing at least a 2.8-fold decrease in expression.

Candidate clone analyses. The 184 clones identified above were retrieved from frozen stocks and plasmid DNA purified for single pass sequencing in the forward direction using the T3 primer in order to generate expressed sequence tags (ESTs) for these clones. These sequences were submitted to the NCBI website for BLASTN and BLASTX database searches in order to tentatively identify them by comparison to the DNA and amino acid sequences of other genes. These data and their analyses are as yet preliminary and require further work. However, initial analyses permitted the tentative identification of most of the clones and their placing into major classes. Some of these clones were of particular interest. Amongst the up-regulated clones we will highlight the following. An ascorbate and a guaiacol peroxidase which

have not been described in cassava so far – peroxidases are known to play important roles in PPD and in a reaction with scopoletin that leads to the blue-black staining of the vascular tissue (Reilly *et al.*, In press). A germin-like protein – these have only recently been described in plants and are involved in stress and defence responses. ACC oxidase – this is involved in the synthesis of the phytohormone ethylene and for which we have already got cDNA and genomic clones. 10 cytochrome P450s – these are one of the largest gene families in *Arabidopsis* and have many different functions from lignin and suberin biosynthesis to the synthesis or catabolism of signalling molecules. Multiple sequence alignment of these clones shows that they fall into four discrete types (Figure 1). Two glucosyl transferases, these catalyse the transfer of sugars to a range of acceptor molecules; in plants glucosyl transferases are a large family of genes and their precise roles and substrate specificities are unclear. Phospholipase – this has a possible role in signal transduction. Amongst the down-regulated clones the following look of

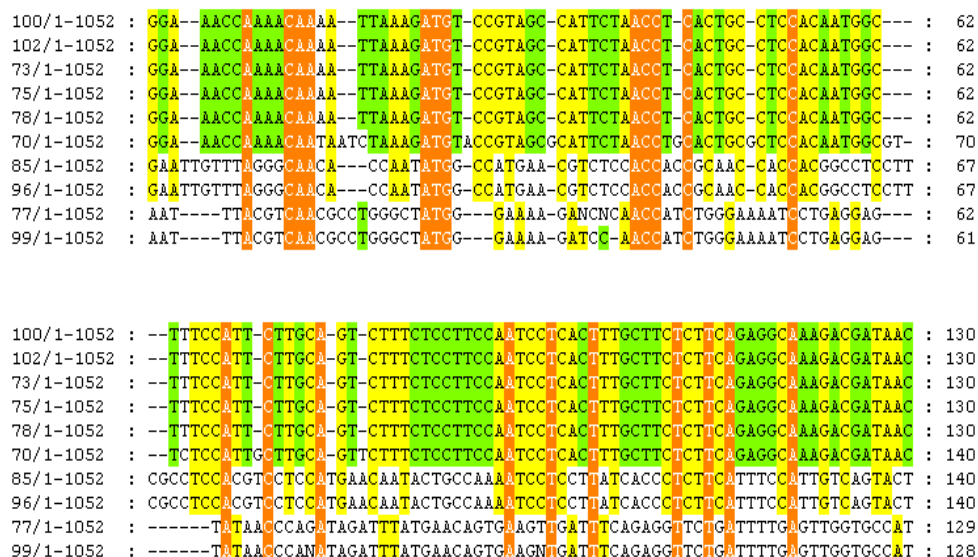


Figure 1: Multiple alignment of cytochrome p450 sequences. The DNA sequences of the 10 cDNA clones tentatively identified as cytochrome P450s were aligned using CLUSTAL. This permitted their assignment to four distinct classes.

particular interest. An auxin-repressed protein – these are often associated with dormancy. An IAA amidohydrolase – these are involved in the regulation of levels of free IAA. ADP ribosylation factor – these are small G-proteins that play a central role in intracellular vesicle transport and some have been shown to regulate phospholipase D activity. A senescence-associated gene – these are involved in programmed cell death.

Discussion

Two PPD-related cDNA libraries were created, one “Early” containing pooled samples from 0, 6 and 12 hours after harvest, and one “Late” from 24, 48 and 96 hours. 11,136 clones from these libraries were hybridised with Cy3 and Cy5 labelled cDNA probes synthesised from mRNA purified from a range of time points over a PPD time course. Four technical replicates of each clone and a selection of control DNAs enabled these hybridisations to be normalised and for clones corresponding to genes whose expression had increased or decreased according to two criteria to be identified. The criteria applied to the down-regulated genes were stricter than those applied to the up, as otherwise an unmanageable number of clones would have been selected. However, it is possible that the criteria used were too strict and that some clones, especially those that show transient changes in gene expression, may have been missed. It is important to point out that these are preliminary data and that it is important to complete a further two sets of biological replicates in order to have full confidence in the results. These biological replicates are currently in progress; when they are ready and their data combined with that discussed here, this will increase the confidence that can be placed in the overall analysis. As a result of which, it may prove possible to relax somewhat the criteria for clone selection, thereby identifying some potentially important clones, particularly those whose expression changes transiently, that have so far been missed. However, database searches

using BLAST enabled some of the clones to be tentatively identified and to be assigned to functional classes, these classes included signalling, oxidative stress and defence. Previous work in our laboratories have identified and highlighted the important roles that oxidative stress and the enzymes and compounds that modulate it play in the PPD response of the cassava root (Buschmann *et al.*, 2000a; Buschmann *et al.*, 2000b; Reilly *et al.*, 2001; Reilly *et al.*, in press). Therefore, it will be of great interest to fully characterise the clones identified here and to evaluate their role in this stress response. In addition the signal transduction pathways leading to the PPD symptoms involve reactive oxygen species (ROS) at certain steps; while these overall pathways are likely to be complex the signalling components identified here, together with those that we have already characterised promise to add to our understanding of this aspect of the response.

Two other studies of the classes of genes expressed during PPD are available; one using cDNA-AFLPs (Huang *et al.*, 2001) and a second using differentially screened and random PPD-related cDNA clones (Beeching, 2001; Gómez-Vásquez *et al.*, 2001). Of the 70 transcript derived fragments (TDFs), 40 were similar to known genes; these included TDFs for genes involved in stress responses, metabolism, signal transduction and development (Huang *et al.*, 2001). Beeching (2001) characterised 92 PPD-related clones, of which 78 could be tentatively identified based on similarity to known genes; a major class of these were cell wall proteins, though it was possible that the methodology used biased the sampling in this direction (Gómez-Vásquez *et al.*, 2001). Other classes included genes involved in the regulation of gene expression, transcription, translation metabolism, signal transduction, stress responses and senescence. It is anticipated that when the current project has advanced further, these studies will complement it and add to the developing picture to the molecular biology of the PPD response.

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Control of sweetpotato virus disease through Farmer Field Schools approach in Kagera region, Tanzania

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Abstract. Sweetpotato, *Ipomea batatas* (L) is an important crop grown for food and income generation in Tanzania. In Kagera region, it is the most important crop grown by resource poor farmers. The crop has recently become even more important due to the decline in banana production due to pests and diseases. Despite its importance, poor soil fertility, pests and diseases affect its productivity. A survey conducted in 2003 indicated sweetpotato virus disease (SPVD) was a major problem that needed immediate attention. SPVD, a disease caused by a synergistic interaction between the white fly-borne Sweetpotato Chlorotic Stunt Virus (SPCSV) and the aphid-borne Sweetpotato Feathery Mottle Virus (SPFMV), is a major threat to sweetpotato production particularly in Bukoba and Muleba districts. Various control techniques including use of resistant varieties and phytosanitation were considered and implemented through Farmer Field Schools (FFS) approach. In the current study the practical procedures on effective implementation of SPVD control techniques based on FFS approach have been explored. Socio-economic factors affecting adoption and farmers' responses to the FFS approach are indicated. Problems related to FFS in Kagera region are documented and solutions suggested.

Introduction

Sweetpotato, *Ipomea batatas* (L) Lam., is globally the second most economically

important root crop after potato (Stather, 2003). It is widely grown in Africa for food and family income generation (Gibson *et al.*, 2002). In Tanzania, the crop is particularly grown by women around the homestead for food and cash in some areas (Kapinga *et al.*, 1995). It is an increasingly income earning crop for farmers close to urban centres in Kagera region. In a 2003 survey, the crop was ranked number one in almost all homesteads particularly in Bukoba district. The importance of sweetpotato as an alternative crop is attributed to low input requirements of the crop, short time to maturity and the ability of the crop to grow well in marginal lands. In addition, the decline in banana productivity due to pests (weevils and nematodes), diseases (panama, black sigatoka) and poor soil fertility makes sweetpotato the best alternative. Most soils in Kagera are dominated by highly weathered kaolinitic soils, characterised by relative enrichment of iron and aluminium hydroxide (Baijukya and Folmer, 1995). Combined with high leaching rate of the soil due to poor structure the effect transforms poor soil fertility problems into an acute one.

Despite the importance of sweetpotato in Kagera, lack of high yielding varieties as well as pests and diseases are the major constraints to its productivity (Rwegasira, 2003). The main disease affecting sweetpotato is sweetpotato virus disease (SPVD), caused by a synergistic interaction between the whitefly-borne (*Bemisia tabacai*), *Sweetpotato chlorotic stunt virus* (SPCSV)

and the aphid-borne *Sweetpotato feathery mottle virus* (SPFMV) (Gibson *et al.*, 1998). SPVD was reportedly wide spread in Bukoba (Gibson *et al.*, unpublished). The disease causes yield loss of between 56–98% (Gibson *et al.*, 1998, Karyeija *et al.*, 1998). There was therefore a need for immediate intervention to alleviate SPVD problems in the region. Various control techniques including use of resistant varieties and phytosanitation were considered and implemented through Farmers' Field School approach.

Farmer Field School (FFS) refer to the experiential learning approach meant to provide farmers with deeper understanding of crop ecology and observational, analytic and problem solving skills which help farmers evaluate the importance and applicability of their existing and innovative practices (Stather, 2003). It is a practice centred on formation of cohesive farmer groups, going through various problems they are facing and identifying possible solutions available. The objectives of the study were i) to assess the effectiveness of FFS in controlling SPVD in farmers' fields and ii) to identify constraints to FFS approach and possible solutions.

Materials and Methods

The preceding survey on SPVD problems in Kagera region by R. Gibson in March 2003, guided the identification of high disease pressure zones. To start with, six sites were identified in Bukoba district at Bugabo, Kanyigo (Nyungwe and Kikukwe), Kanazi, Kyaka and Kyema. These were selected on the basis of readiness of farmers to work in groups and on sweetpotato. Kanyigo, Kyaka and Kyema were the high SPVD pressure zones while Kanazi and Bugabo were the moderate to low SPVD pressure zones. Farmers were sensitised to form groups comprising of not less than 10 members but not more than 25 members. Each group selected their leadership (chairperson, secretary and treasurer) and also made a constitution to guide their decisions. A gap analysis was conducted with each farmer

group to assess what farmers knew, what needed rectification and the whole range of perception of the SPVD problem.

Facilitators for the respective groups were identified through discussion between researchers and farmers. The agricultural extension officers for the respective areas where the FFS is based were seconded by farmers, and they willingly accepted to support the FFS. With emphasis on SPVD, the facilitators were trained on breeding, agronomy, plant protection and post-harvest aspects of sweetpotato, at Maruku Agricultural Research Institute. Thereafter, farmers and facilitators were trained at their respective fields on SPVD. Through FFS, farmers learnt by doing, the various SPVD control techniques. The use of SPVD-resistant varieties and phytosanitation (selection of healthy vines, roguing of SPVD affected plants and isolation) were the principal management techniques tried out by farmers.

Other agronomical and breeding aspects were also practised. Variety suitability criteria used on assessment were farmer-based. Exchange visits among the groups were conducted to allow each group learn from the other through free interactions. Finally a questionnaire was designed to enable farmers and facilitators evaluate the effectiveness of the learning approach they went through and give comments. A total of 97 farmers (in six groups) and four facilitators were interviewed. Farmers were interviewed as a whole group while facilitators were asked to fill in the questionnaire individually. All the responses were compiled to obtain a comprehensive feedback on FFS.

Results and Discussion

The effectiveness of FFS in controlling SPVD. The gap analysis revealed that most farmers knew very little about SPVD. On the contrary, they associated it with physiological disorder caused by drought and poor soil fertility. The 'hands on' strategy where by farmers learnt by doing, through field experiments that were designed to reflect what

they were trained on deepened their understanding. Farmers were able to plant various sweetpotato varieties and test their response to SPVD as well as insect pests, soil fertility and agro-ecologies. The different phytosanitation practices were effectively tried by farmers. Similar findings, as those reported by Gibson *et al.* (2002), were observed during this study that resistant varieties and phytosanitation practices reduced SPVD incidence to negligible levels. Farmers in each group observed and recorded variables they had initially considered important for final evaluation. These included number of sprouted plants, vigour, disease symptoms, insect pests, root setting time and the drought tolerance of the varieties (Table 1). The progress of infector plants incorporated as source of SPVD, new infection on healthy plants and presence of vectors such as whitefly (*Bemisia tabaci*) and aphids were noted. They discussed any strange observations amongst themselves and proposed possible solutions or sought for assistance from the facilitator and the researchers.

Exchange visits among farmer groups augmented their understanding ability. The visits allowed sharing of knowledge and experiences amongst the groups. Many questions about SPVD and dissemination of knowledge to the rest of the community were

asked and answered. The sharing allowed different groups to identify gaps in their respective activities. Drama, laughter and songs composed to either entertain the guests or the hosts had clear message on the control of SPVD for increased food security. Increased farmers' awareness on SPVD was also reflected from the additional criteria that farmers used during the final evaluation of the different trials. The additional criteria include resistance to SPVD, pest damages and root flesh colour. These were considered along with the previously used criteria by farmers (Table 2).

The visitation to FFS members' fields revealed that they are already implementing SPVD control techniques they had learnt, particularly the phytosanitary ones. A total of 53 farmers (Table 3) were practising selection and roguing against SPVD in their own fields that translates to about 55% adoption. However, respondents felt that the number of adopters is small compared to what was expected. Farmers attributed this to the fact that only a few of them had planted sweetpotato after training on SPVD was done. They were optimistic that the number of adopters would have been higher if evaluation was conducted after the new planting season had started. This implies that the rate at which farmers adopt the respective technologies is fast when 'hands on' techniques are

Table 1: Various parameters looked at by the six groups.

Parameter	Farmer groups					
	Abate-kanasha	Jaribu	Juhudi-Lilalo	Neema	Twende na wakati	Umoja
Sprout count	Done	Done	Done	Done	Done	Done
Roguing SPVD affected	Done	Done	Done	Done	Done	Done
Plant vigour	Done	Done	Not done	Not done	Done	Done
SPVD symptoms	Done	Done	Done	Done	Done	Done
Defoliator pest	Done	Done	Not done	Not done	Not done	Not done
Number of diseased plants near infectors	Done	Done	Not done	Not done	Not done	Done
New SPVD infection	Done	Done	Done	Done	Done	Done
Presence of SPVD vector (Whitefly, Aphids)	Done	Not done	Not done	Not done	Not done	Not done
Root setting	Done	Not done	Done	Not done	Done	Not done
Drought stress	Not done	Done	Done	Done	Done	Not done
Vectors population	Done	Not done	Not done	Not done	Not done	Not done

Table 2: Criteria used to evaluate sweet potato varieties.

Criterion	Abate-kanasha	Jaribu	Juhudi-Lilalo	Neema	Twende na wakati	Umoja
A ¹ : Yield	"	"	"	"	"	"
Long storability	"	"	"	"	"	"
Root size	"	"	"	"	"	"
Early maturity	"	"	"	"	"	"
Taste	"	"	"	"	"	"
Starchiness	"	"	"	"	"	"
Resistance to pests	"	"	"	"	"	"
B ² : Resistance to SPVD	"	"	"	"	"	"
Root shape	"	"	"	"	"	"
Root flesh colour	"	"	"	X	X	"

¹A = previously used criteria by farmers. ²B = added (newly included) criteria on recent evaluation.

Table 3: Number of farmers controlling SPVD in their fields.

Group	Abate-kanasha	Jaribu	Juhudi-Lilalo	Neema	Twende na wakati	Umoja	Total
FFS group members	15	29	11	19	10	13	97
Selection of healthy plants and roguing	13	14	6	7	8	5	53
% Adoption	87	48.3	54.5	37	80	38.5	54.6

employed. Thus FFS offers farmers the effective opportunities to solve their own problems.

Generally, FFS - based SPVD control approach was found to be effective in all groups because the approach exploited the idea of farmer knowledge of their own problems and resources available in the surrounding environment. It promoted sense of unity, as a mechanism to track possible solutions to those problems through formation of groups.

Factors affecting FFS. Despite the observed effectiveness of the FFS approach, its full potential has not been realised due to various social, cultural, physical, and economic factors. Among them is false expectation among farmers at a time of group formation. Many farmers joined FFS expecting free funds, farm inputs and other fringe benefits without their efforts. On failing to meet their

expectations a number of farmers left the FFS groups leading to a decline in membership compared to the numbers at the start. On the other hand the deserters created negative publicity to the rest of the community. This presented a social set back to the groups within the communities.

Culturally, sweetpotato is known as a crop for women in Kagera (Ndamugoba *et al.*, 2003). This cultural bias was maintained even during group formation in such away that many groups are largely composed of women (Table 4). This reduced freedom in decision making that led to difficulties in fulfilling most of the FFS plans. At the sametime, cultural division of roles and responsibilities affect FFS activities particularly in groups comprising women only.

The limited availability of arable land has also deterred the success of the approach. Customarily, only a few families own land and

Table 4: Problems that affected SPVD-FFS groups.

Parameter	Abate-kanasha		Jaribu		Juhudi-Lilalo		Neema		Twende na wakati		Umoja	
Sex	M ¹	F ²	M	F	M	F	M	F	M	F	M	F
	0	15	10	19	0	11	0	17	4	6	0	13
Land scarcity	Yes		No		Yes		Yes		No		No	
Social events	Yes		Yes		Yes		Yes		Yes		Yes	
Lack of markets	Yes		Yes		Yes		Yes		Yes		Yes	
Lack of equipment / agric. input	Yes		Yes		Yes		Yes		Yes		Yes	
Low creativity	No		No		Yes		Yes		No		Yes	

¹M=male, ²F=female.

it is only men that decide on the use of a given piece of land. Very often, men give land preference to cash crops such as coffee (Baijukya and Folmer, 1995). Since sweetpotato is regarded as a women crop and most sweetpotato FFS groups were composed of women, access to the land was a problem. This made it difficult to implement some practices such as isolation in controlling SPVD.

Social events and behaviour affected the effectiveness of FFS. In most cases, farmers get involvement in other community responsibilities such as traditional ceremonies, meetings, church responsibilities and political gathering that highly reduced the performances. In addition, such attributes as low level of motivation to adopt new technologies, less participation in contributing to useful ideas, assumption of ideas and tendencies to leave others decide were recorded. These social aspects were found to be characteristics inherent of women in many groups that in turn affected the effectiveness of FFS approach.

False promises were found to limit the success of FFS. Records from previous experiences indicated that agents in various cadres including politicians, project co-ordinators etc, would encourage farmers to form the groups and use them to source funds only to abandon them after getting funds. This discouraged many farmers to join the FFS groups and in turn denied them benefits they would have realised.

Absence of market as a driving force to increased sweetpotato production affected the effectiveness of FFS. This leads to low price payable per agricultural commodity hence low income. Low-income farmers have less ability to purchase necessary equipment and inputs. Some farmers could not afford buying hand hoe and vines for improved varieties. However the low-income to sweetpotato producers seems to be caused by lack of creativity and low motivation to innovation of technologies that would add market value to their products. This was realised in some groups, where farmers feared possible losses of their sweetpotato flesh roots due to lack of markets. The fear emanated from bumper harvests they expected and the easy perishability of flesh root. This probably dictates the need for rising sense of creativity, identify reliable market, good information linkages and FFS-based training on post-harvest technologies, which targets at adding value to sweetpotato products.

Possible solutions to FFS problem. Many suggestions were given as solutions to FFS problems. Respondents indicated that, most socio-cultural problems could be solved through formation of gender balanced FFS groups. This is based on the fact that most decisions would often involve resources, which are afforded by men. Decisions on such issues as land, inputs, time to be spent on group activities, and participation in exchange

visits are all dependent on authorisation from men in households. Involvement of leadership at all appropriate levels would help solve some of the problems including land shortage, venues for meeting and excuse from participating in some activities that would otherwise interfere with FFS schedules. Simple affordable technologies that are appropriate to farmer environment will strengthen FFS. Well-constructed constitutions to defend groups' interests may help consolidate the already established groups and foster the usefulness of FFS approach. Establishment of sweetpotato network from village, ward, division, district, region to the national levels would help with information sharing and easy access to resources and available opportunities.

Conclusion and Recommendations

Through FFS, farmers' circumstances and priority problems facing sweetpotato such as SPVD were easily identified. Proper implementation of FFS imparted sense of ownership and full responsibility of farmers to SPVD management and related technologies that were meant to assist them solve their problems in a practical way. Research about SPVD and transfer of technology were easily implemented while taking care of farmer needs, which allow for exploitation of affordable and cheaply available solutions to farmer problems. The SPVD control strategies developed taking into consideration farmers' circumstances and priorities become sustainable as farmers easily emulated them in their own fields. All these indicate that FFS approach is effective in solving farmers' problems provided that farmers are well guided.

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Screening of cocoyam (*Xanthosoma Sagittifolium* (L) Schott) for disease resistance under two contrasting environments

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Abstract. Sixty-six (66) accessions of cocoyam germplasm collection held by the Plant Genetic Resources Center at Bunso, Ghana were screened for their reaction to the common cocoyam diseases under two different soil moisture conditions. One set was grown under rain fed conditions on the upper slope while the second set was grown at the bottom of the slope where the water table was high. The sites were otherwise similar in soil characteristics, such as pH, organic matter content, fertility and texture. The disease incidence and severity were different in the two environments. The percentages of germplasm attacked by various diseases under the upland conditions were: dasheen mosaic virus 18.2%, bacteria leaf necrosis 36.4%, Phytophthora leaf blight 84.9% and cocoyam root rot blight 77.2%. Under the valley conditions, the disease incidence was dasheen mosaic virus (84.9%), bacterial leaf necrosis (62.1%), Phytophthora leaf blight (9.10%), Cladosporium leaf spot (1.5%), Leptosphaerulina leaf spot 1.5% and Concentric leaf spot (51.5%). The devastating attacks of the Cocoyam root rot blight complex and Phytophthora leaf blight diseases under the upland conditions resulted in no economic yield. However, there was reasonable yield of cormels in the lowland conditions where soft rot complex was not detected and Phytophthora leaf blight was mild.

Introduction

Cocoyam (*Xanthosoma sagittifolium* (L) Schott), a native of the Americas, was

introduced into Ghana by West Indian missionaries in 1843 (Wright, 1930). It thrives well in the humid tropics where rainfall is bimodal and exceeds 1000mm on a well-drained, deep and fertile soil, hence its distribution and cultivation are concentrated in the forest zone of Ghana (Afreh-Nuamah, 1991). Cocoyam is one of the important staple root and tuber crops in Ghana and serves as an important food security crop to most peasant farmers when the cereals and plantain fail or are scarce especially during the perennial “lean” season at the beginning of the rains and, before the harvest of the cereals.

Production levels in Ghana were relatively high in the early sixties, but have suffered considerable decline over the past three decades. According to Dorosh (1988), production levels and yield dropped from 7.6t/ha to 4.7t/ha. The decline is attributed to factors such as changing environmental conditions, deteriorating soil fertility status, inadequate planting materials but worst of all is attack by diseases. In Ghana, no major pest has been linked to the decline in production but diseases especially the cocoyam root rot blight complex (CRRBC or soft rot) and Phytophthora leaf blight cause considerable loss in yield of cocoyam.

Moisture influences the initiation and development of infectious plant diseases in many interrelated ways. It activates bacterial, fungal and nematode pathogens, which may infect the plant. According to Agrios (1988) the underground parts of plants such as roots tubers and young seedlings affected by fungi

like *Pythium* show severity of disease incidence in proportion to the amount of soil moisture and are greatest near the saturation point. The objective of this study therefore, was to assess the extent of susceptibility of the germplasm to the common cocoyam diseases in two environments with differing soil moisture regimes.

Materials and Methods

Two field experiments, one at the upper slope and the other at the bottom of the slope where the water table was high, were established. The planting materials used were obtained from The Plant Genetic Resources Centre at Bunso, Ghana. All the 66 local accessions were used for the experiments. After clearing and removal of dried trash, the upland plot was ploughed, harrowed and ridges, spaced 1m apart, were prepared. Ten corm sets each weighing about 150g for each accession was planted at a spacing of 0.6m on the ridges. At the bottom slope, ridges were prepared without prior ploughing. Planting operations were the same as for the upper slope experiment. Both experiments were planted on 26th May 2001. Cultural practices undertaken at the two sites included weeding, earthening up ridges and raising of embankment to keep water within the valley bottom plots. The water level within the embankment was controlled such that it did not rise above the plants base. Harvesting was done 10 months after planting (10 MAP).

Data were collected on the following parameters starting from 10 weeks after planting (WAP) and regularly at monthly intervals: Number of leaves (both fresh and senesced), petiole length, leaf area, disease

incidence and cormel yield. Other data collected included soil analysis and meteorological data of the two environments as shown in Table 1.

The rainfall pattern for the period was very typical of the forest belt with its two rainfall maxima showing a break in August. For the Upland site, which was rain fed, the total amount of rainfall received during the experimental period was 747.3mm in the major season and 168.3 in the minor season. The valley bottom site received the same amount of rain, in addition to the high moisture table.

Results and Discussions

Growth data. Leaf turnover was measured as the number of leaves appearing and dying. Data taken before the end of the rains (10 WAP), at the end of the rains (18 WAP) and during the dry season (30 WAP) are shown in Table 2. Plant growth in both environments was vigorous up to the end of October 2001, which marked the end of the rainy season (Figure 1a and 1b). Data show that before the end of the rains, the plants maintained an average of 6 leaves all of which remained green or photosynthetic. Toward the end of the rainy season (around 18 weeks) about half of the leaves had been lost due to disease or senescence. The rate of leaf loss increased and by the 30th week, only 2-3 leaves remained green. This was more serious with the upland site (Figure 2).

Up to the 10th week, it would appear that more accessions showed vigorous growth in the lowland environment than the upland one. By the 18th week, vigour of growth as judged by the length or size of petiole was higher under the upland environment than the

Table 1: Soil physical and chemical characteristics at the two sites.

Site	SoilTexture	PH1:25	Carbon (%)	Organic matter (%)	Nitrogen (%)	Available Phosphorus (Mg/kg)	Calcium (Cmol/kg)	Potassium (Cmol/kg)
Upland	Sandy-loam	5.7	0.91	1.57	0.08	11.25	2.20	0.06
Lowland	Sandy-clay loam	6.5	0.63	1.09	0.07	12.50	3.40	0.07

Table 2: Frequency distribution of leaf turnover in the Upland environment.

Leaf turnover at 10 weeks			Leaf turnover at 18 weeks			Leaf turnover at 30 weeks		
No. of leaves (No. dead)	Frequency or No. of accessions		No. of leaves (No. dead)	Frequency or No. of accessions		No. of leaves (No. dead)	Frequency or No. of accessions	
	U ¹	L ²		U	L		U	L
5 (0) ³	5	0	8 (4)	0	3	11 (9)	0	6
6 (0)	25	42	9 (4)	0	6	12 (10)	0	2
7 (0)	36	24	10 (5)	12	57	13 (12)	4	0
			11 (6)	38	0	14 (11)	0	38
			12 (6)	16	0	14 (12)	7	0
						15 (11)	0	19
						15 (14)	21	0
						16 (14)	2	0
						16 (15)	22	0
						17 (13)	0	1
						17 (15)	10	0

¹U = Upland site. ²L = Lowland site.

³Numbers in parenthesis indicate dead leaves due to disease or senescence.



Figure 1a: Growth of accessions 4-5 MAP at the Lowland site.



Figure 1b: Vigorous growth of accessions 4-5 MAP at the Upland site.

lowland one (Figure 3). However, by the 10th month, the top portion of the plants in the upland environment had virtually been lost while the plants in the lowland environment still retained some top growth (see Figure 4).

Leaf area by the 10th week had reached a maximum of 1000cm² in both environments. As occurred with the petiole, plants on the

upper slope appeared more vigorous as the majority had reached maximum leaf area of 1700-1900 and some were in the 2300-2500cm² ranges by the 18th week. In the lowland environment, 42 accessions had maximum leaf area in the 600-800 range and only 4 had leaf area between 1100 and 1200 cm².

As happened with petiole length, by the 30th week, leaf area had been reduced in all environments but a few plants in the upland environment still had higher leaf area than the lowland environment. All these indicate that while cocoyam cannot resist drought very well, it does not grow as vigorously in very wet conditions.

Disease incidence. In general disease incidence was higher in the lowland conditions than the upland as shown in Table 3. Six different diseases were identified in contrast to the four under the upland

conditions. Dasheen mosaic virus disease was more prevalent under the lowland conditions. The main symptom of this disease is wrinkled leaves, which become reduced in size. It would appear that high soil moisture condition promote the movement of the virus, and thus promote the development of the disease. Bacterial leaf necrosis caused by *Xanthomonas compestris* was the next important disease that affected mostly the plants in the high soil moisture environment. This is not surprising since high moisture or humid conditions usually promote bacterial diseases. Concentric leaf spot, which



Figure 2 a: Initiation of senescence of accessions at the upland site at the beginning of the dry season.



Figure 2 b: Initiation of senescence of accessions at the upland site at the beginning of the dry season.



Figure 3: Comparison of growth of an accession under upland condition (left) and lowland environments (right) at 4.5 months (18 weeks).



Figure 4 a: Ten (10) month old materials under lowland conditions still retaining green top-growth.



Figure 4 b: Ten (10) month old materials under upland conditions with much top-growth lost.

Table 3: Percentage of germplasm attacked by various diseases.

Types of disease	% attack	% attack
	Upland	Lowland
Dasheen mosaic virus	18.18	84.85
Bacterial leaf necrosis	36.36	62.12
Phytophthora leaf blight	84.85	9.10
Cladosporium leaf spot	-	1.52
Leptosphaerulina leaf spot	-	1.52
Concentric leaf spot	-	51.52
Cocoyam root rot blight complex	77.24	-

appeared mainly under the lowland conditions, is not an economically important disease (Théberge, 1985).

Cocoyam root rot blight complex. The two most serious diseases of cocoyam, CRRBC and leaf blight mostly occurred in plants grown at the upper slope site. Doku (1980) citing Viennot-Bourgin (1964) stated that the development of CRRBC caused by soil-borne fungi coincides with cormel formation. As a result, cormels of infected plants are no larger than palm nuts. In addition, corms get rotten, produce an offensive odour (Figure 5). Although a few accessions were moderately

susceptible, majority were additively resistant to CRRBC (Table 5).

Cormel yield in lowland environment. Table 4 shows the yields for the germplasm in the lowland environment. The absence of the incidence of CRRBC and the mild leaf blight diseases attack and availability of moisture sustained the growth and productivity of the plants during the period of dry spells. This resulted in the appreciable economic cormel yield (Figure 6).

The main pathogen responsible for CRRBC is *Pythium myriotylum*. It grows best under temperatures of 25°-37°C. Nzietchueng



Figure 5: Corm severely attacked by CRRBC under the Upland condition.



Figure 6: Cormel yield under the lowland conditions.

Table 4: Cormel yield in the lowland plot.

No. of accessions	Cormel yield per plant (kg)	Cormel yield per hectare (tonnes)
11	0.70-1.00	16-20
15	0.51-0.69	11-15
32	0.30-0.50	6-10
8	0.10-0.29	1-5

Table 5: Frequency distribution of percent attack and severity score for CRRBC.

% Attack	No of accessions	Severity score	No of accessions
0	14	1	17
10-30	5	2	12
31-50	13	3	21
51-70	6	4	16
71-90	17		
91-100	11		

(1985) observed that the mean temperature of 26°C, relative humidity of 89% and rainfall of 400-700mm between July and September favour the development of the pathogen in Njambe ecological zone of Cameroon. These were the conditions in the study areas.

Phytophthora leaf blight. Erwin and Ribeiro (1996) citing Gregory (1983) stated that leaf blight caused by *Phytophthora colocasiae* is spread by water-splashed sporangia and

zoospores onto nearby leaf surfaces. The fact that the incidence of this disease was also low under the lowland conditions supports the argument that moisture stress is an important factor, which predisposes cocoyam to attack by the pathogen. As shown in Table 6, most accessions were susceptible to *Phytophthora* leaf blight

Greenhouse screening for CRRBC. The field screening of the accessions for resistance to

Table 6: Frequency distribution of severity score for Phytophthora leaf blight.

Severity (%)	No. of accessions
0-10	0
11-20	1
21-30	12
31-40	7
41-50	25
51-60	14
61-70	4
71-80	3

Table 7: Correlations between some vegetative and yield characters and disease score of the germplasm.

Character	1	2	3	4	5	6	7
1. Total Cormel yield	1	0.214	-0.048	0.084	0.042	0.156	0.866**
2. Total corm yield		1	-0.326**	0.288*	0.006	0.399*	0.184
3. Disease score			1	-0.480**	-0.166	-0.424**	-0.084
4. Plant vigor				1	0.133	0.340**	0.031
5. Mean base circumference					1	-0.065	0.067
6. Mean petiole length						1	0.340**
7. Mean number of cormels							1

*Significant at 0.05 ** Significant at 0.01

CRRBC was followed by screening in the greenhouse. Correlations were established between the various parameters as shown in Table 7. It is clearly shown that disease score was negatively correlated with both growth and yield parameters.

Conclusion

The soil moisture regimes do not only influence the growth and development of cocoyam but the development of diseases. High soil moisture under the lowland conditions (moisture stress) did not favour high vegetative development. However, the water stress was a very important factor that predisposed cocoyam to attack by CRRBC and Phytophthora leaf blight as occurred in the upland environment. This implies that treatments that will conserve soil moisture such as mulching are likely to reduce the attack of these two devastating diseases. Genetic

variation observed in the response of the germplasm especially to CRRBC implies that selection for resistance may be successful.

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Tropical root crops: Opportunities for poverty alleviation through sustainable development

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Abstract. Tropical root crops (TRC) provide unique opportunities for the sustainable development of around 600 million rural poor people in the tropical and subtropical regions of Africa, Asia, South Central America, and Oceania. Many of these rural poor have few practical choices to improve their livelihoods, in particular their long-term social and economic wellbeing. Producing enough food to live well and the ability to exchange the surplus for cash or kind is a critical requirement for long-term poverty alleviation no matter where people live. For the rural poor in the equatorial region of Africa the daily food energy supply from TRC is probably about 65-75% of the requirements and is around 6,500-7,500kj. For this group of rural poor the TRC is their lifeline for survival and a basis for improving their welfare. To assist their long-term poverty alleviation we need to focus more on increasing the supply of TRC and reducing its volatility throughout the year. In the South Pacific TRC already enable significant numbers of rural poor to attain a state of subsistence affluence. TRC, more than any other staple foods produced in the tropics and subtropics, provide great opportunities for long-term rural poverty alleviation through sustainable development. It is generally accepted that economic growth is the key contributor to poverty alleviation in the long-term, provided sensible social and economic policies enable the poor to access the benefits of growth. The rural poor, however, are in a weak position. They usually have restricted access to credit, markets, property rights, infrastructure, technology, and health and education systems.

Underpinning these constraints is the poor people's inability to chip away at the effects of weak governance and poor accountability of public institutions so that their aspirations for a better life largely go unrealised. How can the merits of TRC, such as cassava, sweetpotato, yams, taro, and potatoes, be harnessed to assist poverty alleviation in a sustainable way? This challenge faces all of us in different contexts of our work in TRC and is a worthy cause for our efforts. Long-term poverty alleviation results from the development and maintenance of self-sustaining systems and processes generated from within the affected communities. The first need of the poor is enough life-sustaining food and that it be available safely every day. No poverty alleviation strategy will work if the food issue is not first addressed. Because most TRC consumers are also the producers on their own farms in sometimes very remote rural settings, it makes eminent sense to focus the long-term sustainable development strategies of these people around TRC. This is because the poor in remote rural settings are usually by-passed by the mainstream economic growth that may occur and benefit those in the non-agricultural sectors. This condition where economic growth benefits some and not others magnifies the disparity in income distribution and may even increase poverty for the poorest.

Sustaining livelihoods of the rural poor.

Sustaining the livelihoods of poor TRC producing communities is about sustaining the flow of benefits that can arise out of producing TRC. Producing more TRC can

arise in two ways – through increasing yield and through increasing production area. For most poor TRC farmers access to additional cultivable land to increase their production area is restricted. Therefore the only practical alternative left is through increasing yields. The potential for increasing yields is largely dependent on on-farm resources, technologies practised, and access to knowledge. Increasing yields would enable increasing per capita availability of food but the problem is much more complex because of population growth.

Production growth versus population growth.

Population growth is the critical factor inhibiting per capita increase in TRC availability in the producing regions and thereby the communities' ability to improve food security in a sustainable way. If the rate of population growth is higher than the rate of TRC production growth then there is a fundamental problem for alleviating poverty on a wide scale. In many regions where TRC are produced and consumed the rate of population growth usually averages around 2-2.5 per cent per annum, whereas the rate of production growth averages around 1-1.5 per cent per annum. Obviously over the long-term there is a problem of food security for the rural poor in these regions.

Where population growth is over one per cent higher than production growth, which is the case in several countries and regions of Africa, Asia, South Central America and Oceania, in time food poverty increases and sustainability declines. It is a conundrum that areas where TRC are the main staple foods are also where rural population growth is rapid, thereby threatening the food security. Conversely these are also the areas where alternatives to TRC as staple foods are also limited. Over long-term this condition of increasing negative gap between production growth and population growth results in declining per capita availability of TRC. This threatens community food security and may even lead to starvation. Providing food aid as a short-term measure in such situations may

save lives but is not a long-term sustainable answer to food security. Food aid also creates dependence on imported food and if it continues for long, it imposes a high and unsustainable economic cost to the society. Therefore the negative gap between production growth and population growth remains a counteracting factor to realising the full potential of TRC in assisting sustainable poverty alleviation on a wide scale in poor rural settings where TRC are the main staple foods.

Additional conditions that would assist poverty alleviation.

Increasing the per capita availability of TRC is not enough to achieve poverty alleviation. The poor, depressed areas where TRC farmers eke out a living need additional conditions and supporting resources for improving people's livelihoods. These include greater access to clean water, improved health and education services, better roads and rural transport infrastructure, improved housing, better access to utilities, and increased employment opportunities. The future development of poor TRC farmers is constrained by the lack of these basic needs. Despite these additional constraints to assisting the sustainable development of poor TRC farmers, our main efforts should still be on increasing yields and minimising their volatility, as at least this would help to feed the rural poor, create surplus for exchange and trade, and provide a base from which to improve their wellbeing. This is the challenge that faces us as TRC workers. This is where the efforts of ISTRC and other related institutions should be concentrated in the immediate future.

Production. TRC are important staple foods in the tropical and subtropical regions of the world. Table 1 shows the production of cassava, sweetpotato, yams, taro and potatoes by the major world regions. The world production of cassava is around 173mt, with Africa producing nearly 92mt or 53% of this, with Nigeria responsible for most of this with 33mt. Sweetpotatoes are the next

important TRC with the world production at around 141mt, with Asia dominating with about 129mt or 91%. China is the main producer of sweetpotato at 121mt. The world production of potatoes is around 311mt but only around 20% or about of this is produced in the tropics and the subtropics. Therefore most of the staple production of potatoes is concentrated in the poor and remote highland regions of Asia, North Central America and South America. The fourth most important TRC is yams with the world production of about 38mt, of which 36mt or 96% is produced in Africa. Nigeria produces 26mt, and is the main producer of yams. Taro is the least important TRC with a world production of about 9mt. Africa dominates taro production with 7mt or 78% of the world production. Nigeria is also the main producer of taro with about 4mt produced annually.

Consumption. The consumption of TRC by the major world regions is shown in Table 2. Africa's per capita consumption of TRC totals 200kg with cassava (116kg) and yams (46 kg) being the most important. South America's consumption of TRC is 138kg per capita with cassava at 89kg and potatoes at 44kg. Asia's root crop consumption is 80kg per capita with sweetpotato dominating at 35kg, and potatoes a close second at 31kg. In Oceania the root crop consumption is 106kg per capita. In the tropical regions of Oceania the consumption of cassava, sweetpotato, yams and taro is fairly evenly distributed and all important, totalling 46kg per capita. In Europe and North Central America the per capita consumption of root crops is 194kg and 67kg respectively, which is almost entirely contributed by potatoes.

Table 1: Root crop production (1000t) in 2000.

	Cassava	Sweetpotato	Yams	Taro	Potatoes
Africa	91,849	9,114	36,335	6,666	10,110
North Central America	853	1,112	463	23	30,179
South America	30,759	1,222	496	4	15,144
Asia	49,081	128,812	230	1,873	113,256
Oceania	194	596	292	303	1,830
Europe	-	46	2	-	140,769
World	172,737	140,903	37,818	8,870	311,288

Source: FAO Production Yearbook, 2000.

Table 2: Root crop consumption (kg/capita) in 2000.

	Cassava	Sweetpotato	Yams	Taro	Potatoes
Africa	116	11	46	8	13
North Central America	2	2	1	-	62
South America	89	4	1	-	44
Asia	13	35	-	1	31
Oceania	6	20	10	10	60
Europe	-	-	-	-	194
World	29	23	6	1	51

Source: FAO Production Yearbook, 2000.

Importance of tropical root crops in feeding the world. Some general points can be drawn from the world production and consumption data of TRC. TRC are produced and consumed throughout the world although the dominance of particular root crops varies from region to region. People of many different cultures and traditions rely on TRC as their main staple foods. TRC are common foods in the tropics and subtropics where many of the world's rural poor of around 600 million people live. Africa is the continent where most TRC are produced and consumed, with Nigeria dominating. If it is assumed that only 20 per cent of the world production and consumption of potatoes occurs in the tropics and the subtropics (around 10kg per capita), then TRC contribute around 69kg per capita in feeding the world. This is a significant amount relative to other staple crops produced in the world. When projected on to the consumption of TRC by the rural poor in the tropics and subtropics, then TRC become extremely important since their survival is dependent on these staple foods. It is this group of rural poor people that need immediate and significant development effort in improving their welfare through increasing yields of TRC.

Tropical root crops in Africa. Rural poverty in many parts of Africa is high, especially in countries around the equatorial region where TRC are the main staple foods. What can be drawn from the nexus between these areas of rural poverty and the people's ability to lift themselves out of poverty through the very staple foods that they rely on for survival – the TRC?

Africa is the most important continent in the production and consumption of TRC. Africa produces around 159mt of TRC or 38% of the world production. Nigeria alone accounts for about 64mt. Africa also has a large population, which totaled 794m in 2000 with 441m or 56% deriving their livelihood from the agricultural sector.

Africa exhibited a remarkable growth in per capita consumption of TRC between 1990 and 2000. There has been reduction of the

gap between production growth of TRC and population increase. During this period the production of TRC increased from 113mt to 159mt, an increase of 41%. At the same time the population increased from 619m to 794m, an increase of 28%. The per capita consumption of TRC therefore increased from 183kg to 200kg in the same period.

However, such macro statistics hide regions where there has been a significant widening of the gap between production and population growth. An example is Tanzania where the FAO data shows that the production of TRC declined from around 8.167mt in 1990 to 6.498mt in 2000. During the same period the population increased from 26m to 35m. Interestingly during that decade the population in the agricultural sector increased from 21m to 27m. What factors have caused this apparent massive decline in per capita consumption of TRC from 314kg in 1990 to 186kg in 2000? There are several possibilities and these need further investigation.

Food value of tropical root crops in Africa.

For the rural poor in Africa TRC provide an excellent support base for long-term poverty alleviation since they are already entrenched staple foods. Table 3 shows the food value of TRC in the five largest producers of TRC in Africa. These are Nigeria, Congo Democratic Republic, Ghana, Uganda and Tanzania, which together produce 68% of the 159mt of TRC produced in Africa. These countries are also representative of the main TRC producing zone of Africa – two are from west Africa, two from east Africa, and one from central Africa. An analysis of the per capita availability of TRC and their daily supply of food energy in these five countries shows some interesting results.

There is considerable variation in the amount of kj/capita/day supplied from TRC in the five countries. The supply of kj/capita/day from TRC varies from a high of 9,060 in Ghana, followed by 7,650 in Nigeria, 4,570 in Uganda, 4,460 in Congo Democratic Republic to 2,510 in Tanzania. These figures are

Table 3: Food value of tropical root crops in selected countries of Africa in 2000.

	Nigeria	Congo, Dem Rep	Ghana	Uganda	Tanzania
Production (1000t)	64,236	16,748	12,892	7,842	6,498
Population (1000)	113,862	50,948	19,306	23,300	35,119
Agricultural Population (1000)	37,921	32,202	10,848	18,404	27,454
Kg/capita	564	329	668	337	185
Kj/capita/day	7,650	4,460	9,060	4,570	2,510

Source: Calculated from data in FAO Production Yearbook, 2000

substantial when compared with the average daily kj requirement for an adult at around 10,000kj. The supply of kj/capita/day from TRC for the whole African population is around 2,710kj.

The significance of TRC in supplying the daily food energy is even more important in the rural population. The supply of kj/capita/day from TRC in the rural person's diet is probably more than twice as important as that of urban dwellers. The urban population has both a greater choice and a greater ability to pay for their daily kj requirements than the rural population. For the rural poor in the equatorial region of Africa the kj/capita/day supplied from TRC is probably around 65-75% of the total requirements. Therefore for this group of rural poor people TRC is their lifeline. To assist their long-term poverty alleviation we need to focus both on increasing the supply of TRC and reducing its volatility throughout the year. This is a key challenge for TRC workers.

Food value of tropical root crops in the South Pacific. Even in the small island states of the South Pacific and Papua New Guinea, TRC play an important role in the daily food energy supply. Table 4 shows the food value of TRC in five large producers in the South Pacific. These are Papua New Guinea, Fiji, Solomon Islands, Samoa and Tonga. The data also shows that the supply of kj/capita/day from TRC in the diets of the Pacific islanders is significant.

Detailed studies of the nutritional values of TRC have been carried out in Fiji. In one

village in the Sigatoka Valley, Fiji it was found that TRC supplied around 5,994kj/capita/day, comprising of cassava 3,613kj, sweetpotatoes 1,553kj, taro 410kj, yams 343kj, and potatoes 75kj. This represented 51% of the daily kj requirement of an adult Fijian of 11,750kj (Chandra, 1982). Around 91% of the total daily kj requirement was produced on the consumers' farms.

Attaining subsistence affluence through tropical root crops in the South Pacific.

Subsistence affluence is a concept developed from the observation of subsistence producers and consumers in the South Pacific where TRC are major staple foods. It means that even in a subsistence context people can have a relatively happy and rewarding life if their daily food needs are easily satisfied by the productive resources available to them (a state of bliss with plenty of time left over to undertake leisure activities) (De Boer and Chandra, 1978).

In the South Pacific TRC play a very important part in creating subsistence affluence because of their ability to generate high amounts of food energy per unit of effort. In some areas of Fiji, Samoa and Tonga where subsistence affluence is high, efficiency ratios of 70-85 are commonly attained for cassava, sweetpotatoes, and yams (Chandra *et al.*, 1974). The efficiency ratio for taro is lower but still significant at around 20-25. In the South Pacific, TRC enable large numbers of rural poor people to achieve food security than would otherwise be possible without TRC.

Table 4: Food value of tropical root crops in selected countries of the South Pacific in 2000.

	Papua New Guinea	Fiji	Solomon Islands	Samoa	Tonga
Production (1000t)	1,261	72	134	41	92
Population (1000)	4,809	814	447	159	99
Agricultural Population (1000)	3,707	325	327	-	-
Kg/capita	262	88	300	258	929
Kj/capita/day	3,560	1,200	4,070	3,500	12,600

Source: Calculated from data in FAO Production Yearbook, 2000.

Notes:

(1) In Fiji imports of potatoes probably accounts for another 1,200kj/capita/day, mostly consumed by the Indian population who have a high dietary preference for potatoes, and who form around 46 per cent of the population or 370,000 people.

(2) For Tonga the high level of kj/capita/day is probably due to a much larger fraction of the total production of TRC being exported from this small island nation.

Development lessons for communities relying on tropical root crops.

These examples of the impact of TRC in supplying a large share of the daily kj requirements, and creating better lives for the rural poor in Africa and the South Pacific, have a number of useful lessons and propositions for the future development of TRC. First, let us not forget to use existing staple foods as a vehicle to assist poverty alleviation of the rural poor. History has shown that societies that depend on imported staple foods for a large share of their food needs are often vulnerable to the vagaries of world events and they could pay a high social and economic cost in maintaining their living standards. Second, developed nations developed as a consequence of secure staple food sources, and they started producing a significant surplus for trade or export. The industrial revolution was powered by an agricultural revolution that preceded it. Third, culture, traditions and food preference do matter. TRC have been produced and consumed by societies in different parts of the world for eons. They have proven to be reliable in producing some food in the harshest of conditions by the simplest of technologies with the least amount of purchased inputs. Fourth, the long duration of on-farm availability of the edible parts of

the root crop plant makes it one of the most reliable sources of human sustenance and food security. Considerably more people in the tropics and subtropics would be poverty-stricken if TRC were not produced there. Millions more would have suffered deprivation and even starvation, if it were not for the TRC embedded into the lives of the rural poor.

Conclusions

TRC provide unique opportunities for the sustainable development of around 600 million rural poor people in the tropical and subtropical regions of Africa, Asia, South Central America, and Oceania where TRC are produced and consumed as the main staple foods. In these regions the rural poor have few practical choices for improving their welfare. For them TRC provide a way not only to generate more food with least risk to their meagre resources, but also to enable them to attain a higher degree of subsistence affluence in the future. Food value data from the largest producers in Africa and the South Pacific show that TRC supply a large share of the daily food energy requirements of vast numbers of rural poor people. TRC, more than any other staple foods produced in the tropics and subtropics,

provide great opportunities for the long-term rural poverty alleviation through sustainable development. This is a challenge that faces us as TRC workers, and is where the efforts of ISTRC and other related institutions should be concentrated in the immediate future.

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Crop response of swamp taro to organic sources of nitrogen in lower gangetic plains

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Abstract. Swamp taro (*Colocasia esculenta* L. Schott) is a wet land minor edible aroid grown in flooded or swampy situation. The crop is grown on a small scale particularly in irrigated lowlands or low-lying ditches of eastern India. The crop being a long duration (8 to 10 months) depletes major plant nutrients particularly nitrogen from the soil. Therefore, the field experiments were undertaken to study the nitrogen requirement through organic and inorganic sources in alluvial soil of Lower Gangetic Plains (23.5° N latitude and 89° E longitude and 9.75m above mean sea level) of West Bengal, India during 2001 and 2002. The treatments comprised of different organic and inorganic combinations of 25, 50, 75 % of normal dose of nitrogen (200 kg ha⁻¹) taking mustard cake, neem cake, poultry manure as organic sources and urea as an inorganic source. The stolons (edible part) that initiated from basal sucker corms were harvested periodically at 15-day intervals after attaining suitable marketable length (80 to 100 cm) throughout the stolon bearing period (April to October). Observations on stolon production and yield attributes revealed that inorganic nitrogen source significantly increased stolon production (27.3 tha⁻¹) by 38 to 67 % whereas organic nitrogen sources like mustard cake, neem cake, poultry manure increased the yield (19.7 to 24.3 tha⁻¹) by 21 to 49 % over non fertilized crop (16.3 tha⁻¹). Increased proportions (75 %) of inorganic N-source along with organic N-source (25 %) recorded the maximum stolon production (25.2 tha⁻¹). Interaction effect of N-source and its

combination was found significant and 50% mustard cake + 50% urea recorded the highest stolon yield of 27.6 t ha⁻¹. The stolon length, stolon number basal girth and plant height were significantly influenced by the N-source and its combinations.

Introduction

Swamp taro, a wet land tropical minor edible aroid has long been growing in sub-tropical humid and tropical climate of East Asia. There is an urgent need for substantial increase in production of root and tuber crops to provide food for the ever increasing population (Onwumme, 1999). Swamp taro is one such crop which although considered for the poorer section of the population is gaining importance especially for intensive farming under the low lying humid agro-ecosystem. Swamp taro is made up of two genera viz. *Colocasia* and *Cyrtosperma*. The former produces many stolons from the developing sucker, which are the main edible parts, while the latter hardly produces any stolon but the whole plant including the sucker is edible. The trailing suckers (stolons) emerging from the base of the developing sucker corm serve as important starchy vegetable for the people in areas where traditional vegetables become scarce during monsoon months. Different delicious and palatable dishes prepared from taro are now widely accepted by the middle and upper middle class people. The crop yields between 20-30 t/ha of stolons with lucrative monetary return from a hectare of

land. Swamp taro is a long duration crop covering winter, summer and monsoon seasons. It is normally cultivated in flooded situations and it depletes major plant nutrients from the soil. Researches in India and elsewhere pointed to the need of integrated use of organic and inorganic manures for sustaining the productivity of soil and crops in an intensive cropping system (Tiessen *et al.*, 1994; Sarkar *et al.*, 2003). However, information regarding nitrogen requirement of this crop is very scanty (Pena and Plucknett, 1967; Sen *et al.*, 1999). Therefore, a study was undertaken to determine crop response to organic sources of nitrogen and their combination levels in sandy loam soils of West Bengal, India.

Materials and Methods

Field experiments were conducted at the University Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal which lies at 23.5°N latitude and 89°E longitude at a mean sea level of 9.75 m. Some weather parameters of this area are shown in Table 1. The soils are newly developed alluvial, olive grey in colour, slightly acidic (pH 6.5), clay loam in texture with a bulk density of 1.36 Mg m³. The chemical composition of the soil was organic carbon 0.56%, total nitrogen 0.59%, available P₂O₅ 15.6 kg ha⁻¹ and available K₂O 153.7 kg ha⁻¹.

The trial was made up of 14 treatments comprising of three organic nitrogen sources (mustard cake, neem cake and poultry manure) and their four application levels in addition to urea (100% inorganic source) and an absolute control. The treatment combinations were laid out in a randomised block design with three replications. Organic manure was applied on the basis of equivalent Nitrogen as mustard cake 39 qha⁻¹, neem cake 40 qha⁻¹ and poultry manure 200 qha⁻¹. A common dose of 150 kg P₂O₅ ha⁻¹ and 100 kg K₂O ha⁻¹ was applied as basal. Organic N-sources were applied 10 days before planting. For urea, one third was applied one month after the establishment of the crop and the rest into two equal splits at 30-day intervals.

The stolons were harvested periodically at 15-day intervals starting from April and continued up to October. Stolon production was almost ceased with withdrawal of monsoon (October). Observations were recorded on growth and yield attributes like plant height, basal girth, stolon length, number of stolons per plant, and periodic stolon yield. Data were analysed following the method of Panse and Sukhatme (1989). Sustainable stolon production index (SYI) of swamp taro under different N- sources were analysed with time following the equation proposed by Singh *et al.* 1990 as:

$$SYI = ('Y - d) / Y_{\max}$$

Table 1: Crop weather parameters of swamp taro cultivated in humid tropical climate.

Month	Ep (mm)	Rainfall (mm)	Max.RH (%)	Max.Temp. (°C)	BRS (hrsd ⁻¹)
January	1.6	1.4	99.5	24.7	8.8
February	2.2	9.9	96	29.2	9.4
March	3.6	10.9	95.4	32.5	8.9
April	4.8	46.2	91.8	35.8	8.5
May	4.6	173.9	93	34.2	8.6
June	2.6	250.9	96.2	32.1	3.6
July	2.9	174.8	96.2	31.4	3.9
August	2.7	318.9	96.8	32.8	5
September	2.9	350.6	98.3	32.7	4.9
October	2.3	156.4	98.4	31.6	4.4

where 'Y' is the estimated average stolon yield of each harvesting, d is the estimated standard deviation; $Y_{\max}$ is the observed maximum stolon yield.

Results and Discussion

Effect of N-source. The stolon production of swamp taro was significantly influenced by different organic sources and its proportionate use with inorganic nitrogen. The use of urea increased stolon production (27.3 t ha^{-1}) by 38-67%, whereas, organic sources of nitrogen increased stolon yield ($19.7\text{-}24.3 \text{ t ha}^{-1}$) by 21-49%. Mustard cake and poultry manure were better sources of N compared to neem cake. Das Adhikari *et al.* (1992) also obtained the higher yield of potato from poultry litter (20 t/ha) along with ammonium sulphate (150 kg ha^{-1}). Among the organic sources neem cake recorded 23% less stolon production (19.7 t ha^{-1}) over other organic sources. There was no significant influence of neem cake on tuber yield of potato at higher levels (Sahota and Singh, 1985). Crop growth and yield parameters were much influenced by N-source. The use of inorganic N-source like urea increased plant height, basal girth and stolon length of the crop substantially.

Production consistency of stolon was measured through the yield stability index over time. The results revealed that inorganic N- source had a faster rise and fall of stolon production over the growing period (Table 2). Yield gain was slow but consistent with the use of organic sources of nitrogen and neem cake. The non-fertilized crop had a slow but steady yield gain or fall. Mineralized nitrogen from organic sources meets the crop nutrient requirement slowly but continuously in combination with readily available inorganic nitrogen (Omarhttab *et al.*, 1998 and Sarkar *et al.*, 2003).

Effect of combinations of organic and inorganic N. Crop response to integrated use of organic and inorganic sources of nitrogen was found significant (Table 3). The result

Table 2: Stolon production consistency over time as influenced by N-Source.

N-Source	Yield change (ΔY , $\text{kg ha}^{-1} \text{ day}^{-1}$)					
	April - May	May - June	June - July	July - August	August - September	September - October
Mustard cake	91.3	40.3	42.6	-30.3	-78.6	-34.6
Neem cake	78	33.6	37.0	-31.6	-53.0	-38.0
Poultry cake	12	27.0	19.0	-22.2	-76.6	-42.6
Urea	140.7	36.3	7.6	-57.3	-68.3	-39.0
Control	46.6	36.6	46.0	-11.3	-33.3	-54.6

Table 3: Crop response to nitrogen- sources and its combination levels in swamp taro.

Treatment	Stolon production and its attributes				
	Stolon yield (t ha ⁻¹)	Plant height (cm)	Basal girth (cm)	Stolon (No.plant ⁻¹)	Stolon length (cm)
N-Source (@ 200 kg ha ⁻¹)					
Mustard cake (MC)	23.8	105.4	22	35.7	112.5
Neem cake (NC)	19.7	115.5	17.4	35.5	109.2
Poultry manure (PM)	24.3	109.2	20	35.5	110.2
Urea (U)	27.3	125.8	22.4	38	116
Control* (WN)	16.3	88.1	12.8	28	100
N-Source combination (N _{or} + N _{inorg} %)					
0+100	27.3	125.8	22.4	38	116
25+75	25.2	122.2	22.4	35.6	112.3
50+50	24.3	115.7	21.3	38	114
75+25	21.6	104.1	18.9	34.6	108.6
100+0	19.1	98.1	16.7	34	107.6
CD (P=0.05)					
Source (S)	3.84	12.4	3.53	3.41	5.33
Combination (C)	2.86	10.5	2.22	1.68	3.18
S x C	2.72	6.87	3.44	1.67	2.87

Table 4: Prominent interaction effects of N-source and its combination on stolon production and its yield parameters.

Combination (N _{or} + N _{inorg} %)	Stolon production and its parameters				
	Stolon yield (t ha ⁻¹)	Plant height (cm)	Basal girth (cm)	Stolon No.plant ⁻¹	Stolon length (cm)
MC 25 + U75	26	123.5	22.8	35	117
MC 50 + U50	27.6	114.6	25.5	40	118
NC 50 + U 50	20.4	126	15.4	37	112
PM 50 + U 50	25.2	106.7	23	37	112
PM 25 + U 75	26.6	119.6	23.4	36	111
CD (P=0.05)	2.72	6.87	3.44	1.67	2.89

Table 5: Periodical stolon production as influenced by N-source.

N-Source	Monthly stolon yield (t ha ⁻¹)						δ	SYI	
	April	May	June	July	August	September			October
Mustard cake	0.66	3.4	4.61	5.89	4.98	2.62	1.58	1.75	0.28
Neem cake	0.47	2.81	3.82	4.98	3.98	2.39	1.25	1.47	0.26
Poultry cake	0.55	4.21	5.02	5.59	4.92	2.62	1.34	1.82	0.29
Urea	0.93	5.15	5.79	6.02	4.9	2.85	1.68	1.9	0.23
Control	0.25	1.65	2.75	4.13	3.79	2.79	1.15	1.3	0.25
Mean	0.57	3.44	4.28	5.43	4.51	2.65	1.4		
δ	0.22	1.19	1.04	0.69	0.51	0.16	0.19		
SYI	0.37	0.43	0.57	0.77	0.8	0.87	0.72		

δ - standard deviation; SYI- stability yield index.

revealed that sole inorganic-N recorded 43% increased stolon production over sole organic nitrogen. Among the organic and inorganic combinations-organic 25% + inorganic 75% gave higher stolon yield than the other combinations. Organic 75% + inorganic 25% recorded the lowest stolon production. This was due to availability of higher amounts of readily available nitrogen to the crop, which encourages higher leaf growth of the crop.

Organic and inorganic N source interaction effect was significant for stolon production. Mustard cake 50% + urea 50% resulted into the highest yield (Table 4) whereas, neem cake 50% + urea 50% recorded the lowest.

Periodical stolon production. The monthly stolon production as influenced by organic sources revealed that there was much variation between harvestings from April to October (Table 5). The stolon yield peaked in the month of July irrespective of organic sources and its combinations with chemical fertilizer. Stolon production stability index (SYI) was also high during monsoon months irrespective of nutrient source. High stolon yields might be attributed to higher leaf growth as result of higher degree of air temperature and high intensity of solar radiation (Chan *et al.*, 1998). Among the N-sources, inorganic source like urea recorded higher yields from May to July, whereas, organic sources like mustard cake, poultry manure and neem cake attained maximum stolon production in the month of July. The non-fertilized crop lagged much behind the organic and inorganic source of N fertilized crop.

Conclusion

The integrated use of organic sources of nitrogen with the chemical fertilizers in long duration crop like swamp taro proved beneficial for maintaining consistent stolon production over a long period. Inclusion of organic source to the chemical source in the

proportion of 25% + 75% increased the production of swamp taro in sandy soil of lower Gangetic plains.

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***In-vitro* plant regeneration via somatic embryogenesis and multiple shoot production in an elite ginger cultivar**

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Abstract. Direct production of somatic embryos from the meristematic tissue of elite ginger cultivar ‘Garubathan’ have been developed and more frequently plant regeneration with multiple shoots has been obtained through secondary embryogenesis. Different ex-plants were incubated in the Murashige – Skoog (MS) media with varied concentration of 2,4-D and BAP and sucrose for direct induction of embryogenic calli and promotion of multiple shoots. The rapid initiation and development of somatic embryos were noticed from the meristematic tissue ex-plants cultured in the MS medium with 2% sucrose, 10% coconut milk pulsed with 2,4-D 1mg/l and BAP 1mg/l. The frequency of secondary embryogenic cells production was also higher when cultured in the medium. Response of embryogenic calli regeneration and multiple shoot production varied depending on the strength of the MS medium and concentration of BAP and a consistent production of multiple shoots was achieved on $\frac{3}{4}$ strength MS medium with BAP 5mg/l. Scanning electron microscopy and histological examination of embryogenic calli revealed a clear organised globular and bipolar structures, which hold great promise for germplasm conservation and genetic manipulation of ginger.

Introduction

Ginger (*Zingiber officinale* Rosc.) is an important spice crop in India. It bears high export potential and has emerged as an

important cash crop for Darjeeling Himalayan region. Ginger is propagated asexually through its rhizome parts. There are many varieties of ginger and they differ in their productivity. Agroclimatic conditions also determine its suitability for cultivation. The crop improvement programme is very slow owing to the totally sterile nature of the plant as well as rhizome rot disease complex which affects productivity adversely. Biotechnological approaches have potential for ginger production improvement. Plant regeneration in ginger has been successfully achieved in the past (Hung, 1995; Sharama and Singh, 1997; Malamug *et al.*, 1991). Earning guidance from the past results, a protocol for *in vitro* plant regeneration through somatic embryogenesis will suit the requirement for efficient regeneration of plantlets and multiple shoot production per ex-plant.

There are several reports of *in vitro* clonal multiplication and organogenesis of ginger plants either adventitiously or via somatic embryogenesis from different ex-plants like shoot tips and leaf pieces. For the regeneration protocol to be useful in the development of transgenic plants, it is desirable to develop a tissue culture system that results in repetitive production of embryogenic cells for transformation and several shoots per ex-plant. Genetic transformation has been used successfully in various crop plants for enhanced disease and pest resistance.

The present study aims specifically to develop efficient regeneration protocol in ginger through somatic embryogenesis and produce multiple shoots per ex-plants for future breeding through non-conventional methods.

Materials and Methods

The elite ginger cultivar 'gorubathan' of Darjeeling hills was used in this study and different ex-plants like leaf pieces, shoot tips and meristematic tissues were tried. The different ex-plants were thoroughly washed and sterilised (0.1% Mercuric chloride) and then placed on callus inducing media consisting of Murashige and Skoog (MS) as basal (Murashige and Skoog, 1962), supplemented with different concentration and combination of 2,4-D (0.5–2.0mg/l), benzyl aminopurine (BAP) (0.5-1.0mg/l), coconut milk (CM) 10% and 2.0% sucrose. The pH of the media throughout the study was adjusted to 5.8 (before phytagel application) and poured in the petriplates. All cultures were incubated at 24±2 °C with a 16-h light/8-h dark photoperiod. After few weeks, clumps of embryogenic calli were split into small pieces and placed on the same media for the production of secondary embryogenic cells. In order to regenerate plants from the cultured cells, the callus was incubated in ¾ strength of MS salts with varied concentration of BAP (0.5-5.0mg/l). Once the embryoids were differentiated, they were subcultured in the specified medium in conical flasks and the

regeneration frequency was computed as percentage of embryoids showing at least one shoot.

For scanning electron micrography, embryogenic calli were fixed in 2% glutaraldehyde in 0.1M cacodylate buffer for overnight and post fixed overnight in 1% uranyl acetate. After washing and dehydration with graded alcohol series, tissues were dried with a Tousimis critical point dryer, using liquefied CO₂ as the transitional fluid. Samples were mounted on stubs, sputter-coated with gold and viewed using Phillips 500 scanning electron microscope. For histological studies, well developed embryogenic calli were fixed in formaldehyde-acetic acid-alcohol (FAA), dehydrated in alcohol series and embedded in sequential 5µm sections cut and stained with safranin-fast green.

Results and Discussion

When cultured on a MS medium containing various levels of 2,4-D (0.5-2.0mg/l) and BAP (0.5-1.0mg/l), most ginger ex-plants, with an exception of shoot tips induced both embryogenic and non- embryogenic calli. The frequency of callus formation was highest (83.3%) on culture of meristematic tissues pulsed with 2,4-D and BAP 1mg/l each (Table 1). In contrast, in the same media maximum callus formation from leaf ex-plant was 69.2% callus formation. Callus initiation was lowest when both growth regulators were included at reduced levels. The frequency of

Table 1: Effect of MS media with various concentrations of growth regulators on callus induction from different ex-plants of ginger.

Medium	Different explants of ginger initiated calli (%) *		
	Meristematic tissue	Shoot tips	Leaf pieces
MS salts + BAP 0.5mg/l + 2,4-D 0.5mg/l	25.0	7.69	15.38
MS salts + BAP 1.0mg/l + 2,4-D 0.5mg/l	35.71	12.50	30.76
MS salts + BAP 0.5mg/l + 2,4-D 1.0mg/l	68.0	21.41	38.46
MS salts + BAP 1.0mg/l + 2,4-D 1.0mg/l	83.33	50.0	69.23

* Average of three sets of experiments.

embryogenic calli formation was also higher in the ex-plant of meristematic tissue than leaf pieces. Of 83.3% callus from meristematic tissues, 75% was embryogenic, 17% non-embryogenic and 8% mixed. On the other hand, leaf ex-plants gave 40% embryogenic calli and the remaining was non-embryogenic and mixed types. The typical developmental stages are observed in somatic embryos, which appear distinctly greenish white with a yellowish background of the callus. In a previous report by Kackar *et al.* (1993), 70% embryogenic calli can be achieved from leaf pieces of leaf ex-plants of ginger cultivar 'Eruttupetta'.

Shoot tips of cultivar 'gorubathan' did not show potential of producing embryogenic callus in the test media. Although Malamug *et al.* (1991) suggested the use of MS major elements, Ringe-Nitsch minor elements and organics pulsed with 0.5mg and 1mg/l of 2,4-D and BAP respectively, were responsible for callus induction from shoot tip ex-plants and successful shoot regeneration.

In the subsequent experiments, the rate of regeneration and shoot elongation varied greatly on the four levels of BAP supplemented in $\frac{3}{4}$ strength of MS medium (Table 2). Multiple shoot buds were observed in the study, which appeared distinct from the somatic embryos from meristematic tissues. Maximum shoot regeneration was attained on MS medium fortified with BAP 5.0mg/l. The magnitude of shoot elongation was also high at high levels of BAP 5mg/l. It would seem that in order for shoots to regenerate from

meristematic cell layers in ginger a higher concentration of BAP is required in the nutrient medium. The regenerated plants were well maintained in the MS media without any hormones and successfully established in soil. Ex-plants from leaf pieces and shoot tips have the lowest regeneration rate and multiple shoot formation. While there are many reports on production of ginger plants *in vitro*, most of these protocols are characterized by low frequency of shoot regeneration from embryogenic calli and direct plantlet formation from different ex-plants. Babu *et al.* (1992), Kackar *et al.* (1993) observed a successful shoot regeneration from calli of leaf ex-plants in other ginger cultivars.

Scanning electron microscopic observations provide an evidence of organised globular structures, formation of the scutellar notch and embryoids of direct origin from meristematic tissues. Histological examination of the well developed embryoids revealed a clear bipolar organisation of the shoot and root axis with a distinct scutellum, coleoptile and coleorhiza.

We have developed an expeditious protocol to induce somatic embryogenesis from meristematic tissues ex-plants of ginger cultivar 'gorubathan' from Darjeeling hills. It is evident from the results that the principal mode of plant regeneration in tissue culture of ginger is via somatic embryogenesis. The results also suggested that more regenerates can be obtained, because the meristematic zone located deeper in the tissue of ginger may also be induced to regenerate plants. This system has been employed in our laboratory to successfully regenerate ginger plants, which will promote rapid production of disease free planting materials and further breeding programme for the improvement of ginger.

Table 2: Effect of benzyl aminopurine (BAP) on the growth and multiple shoot formation in ginger via somatic embryogenesis.

Concentration of BAP	Maximum Number of Shoot/callus	Shoot length after one month of growth (cm)
$\frac{3}{4}$ MS + 0.5 mg/l	2.30	3.0
$\frac{3}{4}$ MS + 1.5 mg/l	3.40	3.0
$\frac{3}{4}$ MS + 3.0 mg/l	5.75	5.0
$\frac{3}{4}$ MS + 5.0 mg/l	8.15	7.5

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Morphological and biochemical characteristics of promising Indian sweetpotato cultivars and identification of virus infecting sweetpotato in India

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Abstract. Phylogenetic relationship of twenty-two promising Indian sweetpotato (*Ipomoea batatas*) cultivars was determined through morphological and yield parameters. Mahalanobis Multivariate D² analysis was performed with a view of tracing relationship among the cultivars. Based on sixteen significant characters, four distinct clusters (Gr. I- 11, Gr.II- 9, Gr.III- 1 and Gr.IV- 1) were obtained. This grouping was concordant with the other characters used in cladistic analysis. Association of morphological characters with yield and yield attributing factors were also studied to work out the direct or indirect effect of different characters on yield. The biochemical parameters of the tubers viz. carbohydrate, crude and soluble protein, ascorbic acid, dry matter content were determined. Significant variation of the proximate nutritional composition was observed in the tested cultivars. The mineral profile viz. Fe, Mn, Cu and Zn in the tubers was different among the cultivars. Occurrence of the viruses among the cultivars was also determined visually and by NCM-ELISA. Twelve different types of virus symptoms were found in the test cultivars. NCM-ELISA gave positive results for some viruses. The present studies have provided a detailed insight among the twenty-two sweetpotato cultivars, which would

contribute to the crop improvement programme.

Introduction

Sweetpotato (*Ipomoea batatas* L. (Lam) is considered to be the world's most important subsistence crop (Hall, 2003). This crop is grown mostly in China, followed by Sub-Saharan Africa, Indonesia and India. Over 98% of global sweetpotato output is currently cultivated and consumed in developing countries. In India sweetpotato cultivation is increasing dramatically, with cultivation mostly in Orissa, Bihar, Uttar Pradesh, West Bengal and in South-Indian states (Edison, 2000). The average productivity of sweetpotato is, however, declining as a result of several biotic and abiotic factors. Thus, there is an urgent need for selection and development of high yielding improved cultivars. The rich genetic biodiversity of sweetpotato in India offers prospects of broadening the genetic base to incorporate highly adapted, high yielding cultivars (Naskar, 1996; Thomas and Raman, 2000). Thus information of genetic diversity and relationships among the genotypes of sweetpotato is essential for efficient utilization of the genetic resources. The crop exhibits great diversity in morphological and

phenotypic traits. In biosystematics, mature morphological features and the biochemical studies are the conventional criteria used to establish taxonomic status, which provide a formidable set of characters for correlation with other features and 21 key sweetpotato descriptors such as growth habit, mature leaf shape, color, foliage and floral characters, tuber colour its quality have been described (Huaman, 1992). Sweetpotato is the crop with high contents of dietary fiber, complex carbohydrates, protein, vitamin A, C and B6, and minerals. It contains virtually no fat and are low in sodium. Presently sweetpotato is receiving much attention in human nutrition and in animal husbandry. The assessment of biochemical characters will provide data that will supplement conventional quality parameters. Several reports on the nutritive values of the sweetpotato and differences in the cultivars have been studied (Bradbury *et al.*, 1985; Ravindran *et al.*, 1995; Hall, 2003). In recent years, post harvest processing of sweetpotato has become popularized and opening up a new dimension for farmers and entrepreneurs. Though the crop has high adaptability and tolerance to abiotic stresses, one of the major constraints for its production is attack by virus diseases. Several researchers have made intensive studies on the occurrence of several sweetpotato viruses, their severity and yield loss in different countries but only a little effort has been made in India. The current challenge is to utilise novel Indian sweetpotato genetic resources to broaden the genetic base for improvement of the crop into high yielding, nutritive and disease resistant cultivars.

In the present investigation, phenotypic diversity of twenty-two Indian cultivars were studied. Nutritive value of the selected cultivars was analyzed for proximate composition of carbohydrate, proteins, vitamin-C and minerals. The variation in the symptoms on virus-like diseases in the test cultivars were studied and detected by NCM-ELISA.

Materials and Methods

Some promising Indian sweetpotato cultivars viz. Tripty, IBM-95-229, WBSP-4, IBM-95-220, Kamala Sundari, Pol-20-6-2, Pol-4-4-5, BCSP-14, IBM-95-206, BCSP-10, RNSP-1, RNSP-2, IGSP-6, IGSP-7, IGSP-8, IGSP-9, NDSP-9, NDSP-10, BCSP-7, CO-3 were characterized for the morphological parameters, nutritional content and qualitative traits based on descriptors of Huaman *et al.* (1992) and Das and Mukherjee (1996). The experiments were conducted at the Horticultural Experimental Field of Bidhan Chandra Krishi Viswavidyalaya, Kalyani during 2000-2003. The vines of the cultivars were planted at inter row and intra row spacing of 60 x 20 cm, respectively, in a Randomised Block Design. Data on the morphological parameters like plant habit, vine characters including stem and foliage characters, floral descriptions and crop canopy were recorded 90 days after planting. Leaf area index (LAI) was determined using Sun Scan type SS-1CE Delta T-devices (UK) model canopy analyser. Tuber yield was determined for five plants randomly selected from each plot and converted to yield/ha after 120 days. The observation on physical characters like colour of stem, leaves, flowers, floral parts and tubers were recorded from fresh samples. The multivariate divergence analysis based on Mahalanabis D² statistics method (Chowdhury and Singh, 1995) was performed to assess the genetic variability, intensity and genetic distance, cluster analysis among twenty-two sweetpotato cultivars in respect to sixteen morphological characters, yield components.

The proximate nutritional composition of the cultivars were analysed from fresh tubers after harvest. Dry matter content was estimated as the difference between the fresh and dry tuber weight of each cultivar following oven drying of tuber slices at 60° C for 72 hr. Total carbohydrate, crude protein, vitamin C, and mineral compositions were determined on dry weight basis (dwb) and

soluble protein on fresh weight basis (fwb) for each cultivar. The freshly harvested tubers of uniform size were washed thoroughly, sliced, sun dried and then oven dried at 60° C for 18 hr. The dried slices were ground into a fine powder and stored in airtight containers until use. Total carbohydrate was determined by Anthrone method. Crude protein was estimated from nitrogen content by Micro-Kjeldahl method (Sadasivam and Manickam, 1997). The soluble proteins in fresh tubers were precipitated with 10% trichloroacetic acid (TCA), dissolved in 1N NaOH and analysed spectrophotometrically according to Lowry (1951). The method for analysing vitamin C was based on titration with 2,6-dichlorophenol-indophenol (Sadasivam and Manickam, 1997).

The analysis of mineral composition like iron, manganese, copper and zinc were carried out by digesting the samples with perchloric, nitric and acetic acid mixture and determined by atomic absorption spectrophotometer.

The natural incidences of sweetpotato virus like diseases were determined. Characteristics symptoms were also noted. The fresh leaf samples from the plants showing symptoms were tested using NCM-ELISA for the presence of eight viruses namely: sweetpotato (SP) feathery mottle virus (SPFMV), sweetpotato mild mottle virus (SPMMV), sweetpotato latent virus (SwPLV), sweetpotato chlorotic flecks virus (SPCFV), sweetpotato mild speckling virus (SPMSV), C-6 virus, sweetpotato chlorotic stunt virus (SPCSV) and sweetpotato caulimo like virus (SPCaLV). The detection of the viruses by NCM-ELISA was done according to International Potato Centre (CIP) method. The NCM-ELISA kit was also kindly provided by the CIP, Peru.

Results

The data of Mahalanobis multivariate divergence analysis on the morphological and yield determining factors are summarized in

Table 1. A significant phylogenetic diversity and links among the cultivars was observed.

The analysis of variance showed highly significant differences among the twenty-two sweetpotato cultivars for all characters (Table 2). Most of the characters showed high heritability; tuber yield, carpel length, flower length, flower diameter and LAI. The estimated genetic advance (GA) values were found to be very high in the characters for vine length, tuber yield, tuber length and inflorescence length and lowest for tuber weight (Table 2). A very close relationship of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed among most of the characters while lamina length, anther length and number of tubers per five plants showed wide differences between GCV and PCV.

Genotypic and phenotypic correlations were calculated for sixteen characters (Table 3). At phenotypic level, flower length and diameter and sepal length had a significant correlation with yield. At the same time flower diameter, sepal length and number of tubers also showed a positive correlation. Similarly, flower length and diameter, length of sepal and anther were also found to be positively correlated with yield.

The genotypic and phenotypic path coefficient analysis revealed direct and indirect effects of most morphological traits on tubers (Tables 4). Among the sixteen characters considered in this study, all with the exception of character X_{15} (number of tuber per five plants) were introduced in the path coefficient analysis of yield at both genotypic and phenotypic levels. Among the significantly correlated morphological characters like flower length and diameter, sepal length and anther length had a positive effect on the yield. On the other hand, stamen length (X_9) and LAI (X_{12}) did not show significant correlation with yield.

The divergence analysis (Table 5 a, b, c) revealed different cluster combinations at specific similarity level or genetic distance (D). This analysis generated two major clusters (I

Table 1: Mahalanobis multivariate D² analysis of twenty-two Indian sweet potato cultivars with respect to the morphological and attributing factors.

Sweet potato cultivars	1.Vine length	2.Petiole length	3.Lamina length	4.Inflorescence length	5.Pedicle length	6.Flower length	7.Flower diameter	8.Sepal length	9.Stamen length	10.Anther length	11.Carpel length	12.LAI	13.Tuber length	14.Tuber breadth	15.Weight of tuber/5 plants	16. Tuber yield (t/ha)
Tripty	93.67	11.5	8.67	7.9	0.67	3.65	2.88	1.2	1.65	0.5	2.2	0.8	17.83	4.67	2.77	38.13
IBM-95-229	64.17	12.57	7.67	6.47	0.5	3	2.67	0.87	0.9	0.25	1.15	1.5	15.5	3.25	2.2	32.27
WBSP-4	80.5	13.9	9.83	16.33	1.33	4.15	3.5	1	1.7	0.4	2.15	1.7	18.23	4.67	2.6	38.33
IBM-95-220	96.73	14.2	11.37	10.8	0.9	3.9	3.35	1	1.85	0.5	2.07	1.6	17.47	3.77	1.23	22.43
Kamala Sundari	101.8	11.27	9	14.67	1.47	5	4.55	1.47	1.05	0.5	1.1	2.2	15.27	7.53	2.63	32.9
Pol-20-6-2	40.53	8.4	9.37	5.6	0.67	4.35	3.5	1	0.95	0.3	1.2	0.1	16.3	5.23	1.21	20.25
Pol-4-4-5	92.9	12	8.77	10.43	0.83	3.65	3	1.03	1	0.3	1.17	0.9	14.07	4.97	1.1	18.44
BCSP-14	81.7	7.77	9.57	6.7	0.97	3.55	3.1	0.93	1.1	0.35	2	0.9	18.47	6.93	2.06	20.97
S-1221	87.67	11.53	8.13	12.67	0.97	3.6	3	1.07	1.2	0.2	1.75	0.9	25.33	7.9	1.95	32.45
BCSP-5	70.7	11.83	8.4	7.5	1	4.1	3.5	0.97	1.1	0.3	1.57	1.1	12.9	3.77	2.23	35.8
IBM-95-206	73.4	9.73	8.57	10.77	0.87	2.43	3.97	0.73	1.1	0.3	1.3	2.4	23.47	4.83	1.15	18.3
BCSP-10	120	13.8	8.6	6.27	1.07	3.5	2.9	1.03	0.9	0.35	1.2	1.1	20.1	6.83	1.1	18.2
RNSP-1	79	13.63	9.47	6.67	0.53	3.15	2.65	0.8	1	0.2	1.5	2	15.33	3.4	0.16	2.55
RNSP-2	53.17	9.47	8.8	8.2	0.8	3.3	2.8	0.9	1.2	0.25	1.7	1.9	10.33	4.77	0.54	6.9
IGSP-6	64.17	11.1	9.23	10.63	0.93	2.75	2.4	1	1.6	0.4	2	2.1	19.37	4	22.78	10.5
IGSP-7	70.33	17.2	10.47	6.17	0.63	3	2.8	0.97	1.55	0.25	1.9	2.1	13	4.4	0.68	9.77
IGSP-8	92	11.57	7.87	13.4	0.97	4.1	3.65	1	1	0.35	1.5	3	18.27	4.4	0.95	15.55
IGSP-9	89.67	15.2	9.03	11.17	1.07	3.3	2.85	0.97	1.5	0.3	1.95	2.3	22.77	6.13	1.23	20.77
NDSP-9	85.83	7.47	8.93	9.7	1.67	2.65	2	0.87	0.9	0.2	1.2	0.6	16.9	3.83	1.05	15.3
NDSP-10	65	9	9.47	9.47	1.1	3.4	3.15	1.13	1	0.3	1.9	0.9	15.63	3.9	28.98	15.83
BCSP-7	76	7.47	7.53	9.73	0.73	3.35	2.65	0.8	1.6	0.35	2.1	1.3	17.4	4.43	1.27	20.6
CO-3	85.67	12.13	8.23	14.2	0.93	3.6	2.5	0.93	0.8	0.3	1.1	1.1	19.3	3.7	0.65	10.8
SEM±	8.42	12.92	54.17	8.22	7.81	52.92	62.89	37.61	41.2	0.19	28.8	10.1	8.32	25.79	7.7	70.18
LSD (p>0.05)	24.08	36.88	15.46	23.46	22.3	151.1	179.5	107.3	117.6	NS	8.7	28.8	23.7	73.61	21.98	20.03

Table 2: Analysis of genotypic and phenotypic variability in twenty-two Indian sweet potato cultivars.

Character	HeritabilityB.S	GA (K=2.06)	Genotypic Coefficient of variation (%)	Phenotypic Coefficient of variation (%)
X ₁ Vine length	0.520	22.52	18.91	26.23
X ₂ Petiole length	0.501	3.27	19.53	27.59
X ₃ Lamina length	0.366	0.89	7.96	13.16
X ₄ Inflorescence length	0.811	5.48	30.15	33.47
X ₅ Pedicel length	0.804	0.51	29.28	32.65
X ₆ Flower length	0.977	1.21	16.89	17.09
X ₇ Flower diameter	0.965	1.15	19.17	19.52
X ₈ Sepal length	0.837	0.28	14.97	16.36
X ₉ Stamen length	0.951	0.63	25.93	26.59
X ₁₀ Anther length	0.040	0.03	18.41	92.00
X ₁₁ Carpel length	0.985	0.80	24.2	24.39
X ₁₂ LAI	0.942	1.40	47.55	49.01
X ₁₃ Tuber length	0.851	6.55	19.78	21.44
X ₁₄ Tuber breadth	0.892	2.58	27.14	28.65
X ₁₅ Weight of tuber per 5 plants	0.000	0.0	0.86	364.51
X ₁₆ Tuber yield (ton/ha)	0.986	20.91	49.2	49.55

and II) and two small clusters consisting of a single cultivar each. The clusters I and II (Table 5a) comprised of eleven and nine cultivars respectively. The single cluster cultivars were WBSP-4 and Kamala Sundari. Average performance and inter and intra cluster distance showed considerable variations among the groups (Table 5b). Cultivars in cluster II were distantly related with the cultivars of cluster IV, whereas low genetic distances were found between the cluster II and III. Cluster analysis based on the sixteen morphological characters and yield attributes are summarized in Table 5c. Tuber yield, LAI, carpel and flower length had the highest level of divergence of 29.44, 24.68, 20.35 and 10.82% respectively. These are the most indiscriminate characters among the cultivars. High values for characters length of vine, pedicel, flower, sepal and anther flower diameter and LAI were observed in cluster IV. Cluster I had the lowest value of petiole and anther length, LAI, and tuber yield. Clusters III showed maximum lamina, inflorescence, sepal and carpel length, and total tuber yield.

Variations were also observed in the qualitative and physical characteristics (Table

6). The colour of stem, leaf, leaf veins, petiole, sepal surface and shape, colour of filament and anther, style length, tuber skin and flesh colour had positive correlation with genotypic and phenotypic coefficient of variation. The cultivars, WBSP-4 and Kamala Sundari from groups III and IV were quite distinct from other cultivars.

Significant differences were observed among tubers for dry matter content and total carbohydrate (Table 7). The average dry matter ranged from 15.62% to 28.83%. Total carbohydrates were also high (37.20%). The average crude and soluble protein content varied from 1.85 to 9.33% (dry weight basis) and 25.9 to 6.61 mg/gm⁻¹ (fresh weight basis), respectively. Among the cultivars, orange skinned Kamala Sundari, and red skinned BCSP-5, IBM-95-229, IBM-95-220 had high levels of crude and soluble proteins although S-1221 and NDSP-9 had the highest amounts of soluble protein. Vitamin-C content was significantly influenced by cultivars and ranged from 10.88 to 35.39% (dry weight basis). Most of the cultivars were very good source of minerals and significant levels of

Table 3: Genotypic and phenotypic correlation among sixteen morphological descriptors.

	X ₁ Vine length	X ₂ Petiole length	X ₃ Lamina length	X ₄ Inflorescence length	X ₅ Pedicel length	X ₆ Flower length	X ₇ Flower diameter	X ₈ Sepal length	X ₉ Stamen length	X ₁₀ Anther length	X ₁₁ Carpel length	X ₁₂ LAI	X ₁₃ Tuber length	X ₁₄ Tuber breadth	X ₁₅ Weight of tuber/5 plants	X ₁₆ Tuber yield (ton/ha)
X ₁																
X ₂	0.413															
X ₃	-0.2	0.421														
X ₄	0.405	0.115	-0.09													
X ₅	0.435	-0.23	0.106													
X ₆	0.246	0.069	0.106													
X ₇	0.193	0.153	0.222													
X ₈	0.442	0.182	0.2	0.303	0.4	0.71	0.761	0.25	0.004	0.08	-0.06	0.09	0.272	0.305	-0.02	0.174
X ₉	0.054	0.39	0.572	0.19	-0.11	-0.01	0.043	0.04	0.232	0.19	0.086	0.35	0.077	0.001	-0.11	0.026
X ₁₀	0.499	0.5	0.552	-0.17	-0.81	0.29	0.348	-0.1	0.355	0.22	0.272	0.01	-0.19	-0.1	0.047	-0.13
X ₁₁	-0.08	0.126	0.477	0.041	-0.12	-0.07	0.012	0.01	0.133	-0.1	0.037	0.32	0.326	0.137	-0.02	0.229
X ₁₂	0.152	0.487	0.04	0.373	-0.02	-0.11	0.073	-0.1	-0.06	-0.14	-0.09	0	0.157	0.238	0.105	0.201
X ₁₃	0.429	-0.02	-0.19	0.395	0.18	-0.19	-0.25	-0.1	0.105	-0.3	0.1	0.07	0.096	0.435	-0.09	0.48
X ₁₄	0.48	-0.08	-0.05	0.172	0.34	0.37	0.391	0.5	-0.06	-0.66	-0.03	-0.1	0.444	0.404	0.003	0.173
X ₁₅	58.67	-48.4	43.05	18.12	21.3	-40.8	-16.9	60.4	16.74	-63.5	65.43	-12	-1.11	-40.2	-0.11	0.281
X ₁₆	0.244	0.04	-0.21	0.251	0.22	0.49	0.457	0.46	0.233	-0.67	0.154	-0.2	0.186	0.302	-33.8	-0.06

iron (Fe), manganese (Mn) and copper (Cu) were detected.

The preliminary indexing of twenty-two cultivars for sweetpotato virus diseases in the field was made on the basis of symptoms appearance. Symptoms ranged from mild to severe and included chlorosis, vein clearing, stunting and feathery mottle like symptoms. Following serological tests using NCM-ELISA, the viruses detected were: SPCSV, SPFMV, SOMMV, SPCaLV, SPCFVM SPMSV and C-6.

Discussion

The advantage of using the phenotypic characters in systematic studies is subjected to the diversity of factors that prevail in the case of mature plants. In the present study, morphological parameters were useful in resolving the cultivars of sweetpotato and making probable links. The closer the value of GCV towards PCV implicated less environmental impact on the characters studied. It is suggested that fourteen characters are controlled by the gene action with the environment having little influence. Lamina length and weight of tuber per five plants are controlled by environmental factors with gene action playing a minimal role.

Geographical distribution of the sweetpotato cultivars was not related to genetic diversity (Naskar, 1996). Somda and Kays (1990) also made similar observation on the change in petiole and lamina length and leaf size with the season. It is suggested from our results that the characters of vine, inflorescence and tuber length and total tuber harvest are the important contributing factors during direct selection of sweetpotato lines. Rajendran and Amma (1996) considered the flower characters one of the important descriptors to understand the spectrum of variation in the traits of sweetpotato for a breeding programme. In our study, it is evident that flower length and diameter and length of sepal and anther have positive correlation with tuber yield. The genetic uniformity and non-uniformity is reflected by the genetic

Genotype														
1	1.175	-0.103	0.153	0.922	-0.508	-2.265	1.974	-0.725	0.101	0.030	0.132	-0.502	-0.095	-0.044
2	0.486	-0.249	-0.321	0.261	0.274	-0.640	1.565	-0.299	0.729	0.030	-0.199	-1.607	0.004	0.007
3	-0.236	-0.105	-0.763	-0.211	-0.123	-0.974	2.273	-0.328	1.069	0.033	-0.754	-1.132	0.041	0.005
4	0.475	-0.029	0.071	2.279	-0.721	-3.182	2.908	-0.496	0.354	-0.010	-0.065	-1.230	-0.087	-0.016
5	0.512	0.058	-0.080	1.406	-1.168	-2.189	2.412	-0.662	-0.202	-0.048	0.190	0.057	-0.040	-0.031
6	0.289	-0.017	-0.081	0.786	-0.277	-9.223	9.712	-1.166	-0.020	0.017	0.113	0.351	0.042	-0.034
7	0.227	-0.038	-0.170	0.648	-0.276	-8.766	10.218	-1.247	0.080	0.021	-0.018	-0.241	0.056	-0.036
8	0.519	-0.045	-0.153	0.690	-0.471	-6.557	7.771	-1.640	0.120	-0.005	-0.014	0.269	0.020	-0.046
9	0.063	-0.097	-0.436	0.432	0.126	0.100	0.436	-0.106	1.868	0.013	-1.353	-0.795	-0.023	0.006
10	0.586	-0.125	-0.421	-0.396	0.943	-2.624	3.557	0.151	0.393	0.060	-0.363	-2.555	0.065	0.060
11	-0.098	-0.031	-0.364	0.094	0.140	0.660	0.120	-0.014	1.599	0.014	-1.581	-0.364	-0.022	0.003
12	0.179	-0.121	-0.030	0.849	0.020	0.981	0.745	0.134	0.450	0.046	-0.175	-3.300	-0.016	0.006
13	0.504	0.005	0.143	0.900	-0.212	1.753	-2.578	0.147	0.196	-0.018	-0.158	-0.234	-0.220	-0.041
14	0.564	0.020	0.038	0.392	-0.398	-3.419	3.991	-0.820	-0.114	-0.039	0.047	0.232	-0.098	-0.092
Residual effect = 0.0025														
b. Phenotypic														
1	0.084	0.022	-0.049	0.014	0.018	-0.050	0.131	0.006	0.002	-0.003	0.015	-0.048	0.071	-0.039
2	0.022	0.084	-0.108	0.002	-0.008	-0.013	0.098	0.001	0.132	-0.006	-0.020	-0.177	0.020	0.000
3	0.012	0.026	-0.352	-0.004	0.004	-0.016	0.111	0.002	0.201	-0.006	-0.064	-0.003	-0.049	0.013
4	0.021	0.003	0.022	0.057	0.024	-0.091	0.210	0.007	0.076	0.003	-0.009	-0.162	0.085	-0.017
5	0.028	-0.012	-0.025	0.026	0.053	-0.060	0.161	0.007	-0.034	0.004	0.022	0.019	0.041	-0.030
6	0.014	0.004	-0.018	0.017	0.010	-0.303	0.777	0.014	-0.006	-0.001	0.017	0.045	-0.047	-0.043
7	0.013	0.010	-0.047	0.014	0.010	-0.280	0.839	0.015	0.025	-0.001	-0.003	-0.040	-0.063	-0.047
8	0.021	0.003	-0.030	0.018	0.016	-0.196	0.577	0.022	0.031	0.000	0.001	0.026	-0.016	-0.055
9	0.000	0.019	-0.125	0.008	-0.003	0.003	0.037	0.001	0.568	-0.001	-0.195	-0.113	0.020	0.008
10	0.007	0.016	-0.076	-0.006	-0.007	-0.010	0.025	0.000	0.027	-0.030	-0.011	-0.053	-0.024	0.010
11	-0.005	0.007	-0.096	0.002	-0.005	0.021	0.010	0.000	0.473	-0.001	-0.235	-0.047	0.025	0.005
12	0.008	0.029	-0.002	0.018	-0.002	0.027	0.067	-0.001	0.127	-0.003	-0.022	-0.506	0.018	0.008
13	0.023	0.006	0.066	0.019	0.008	0.054	-0.202	-0.001	0.044	0.003	-0.023	-0.035		

Genotype														
1	1.175	-0.103	0.153	0.922	-0.508	-2.265	1.974	-0.725	0.101	0.030	0.132	-0.502	-0.095	-0.044
2	0.486	-0.249	-0.321	0.261	0.274	-0.640	1.565	-0.299	0.729	0.030	-0.199	-1.607	0.004	0.007
3	-0.236	-0.105	-0.763	-0.211	-0.123	-0.974	2.273	-0.328	1.069	0.033	-0.754	-1.132	0.041	0.005
4	0.475	-0.029	0.071	2.279	-0.721	-3.182	2.908	-0.496	0.354	-0.010	-0.065	-1.230	-0.087	-0.016
5	0.512	0.058	-0.080	1.406	-1.168	-2.189	2.412	-0.662	-0.202	-0.048	0.190	0.057	-0.040	-0.031
6	0.289	-0.017	-0.081	0.786	-0.277	-9.223	9.712	-1.166	-0.020	0.017	0.113	0.351	0.042	-0.034
7	0.227	-0.038	-0.170	0.648	-0.276	-8.766	10.218	-1.247	0.080	0.021	-0.018	-0.241	0.056	-0.036
8	0.519	-0.045	-0.153	0.690	-0.471	-6.557	7.771	-1.640	0.120	-0.005	-0.014	0.269	0.020	-0.046
9	0.063	-0.097	-0.436	0.432	0.126	0.100	0.436	-0.106	1.868	0.013	-1.353	-0.795	-0.023	0.006
10	0.586	-0.125	-0.421	-0.396	0.943	-2.624	3.557	0.151	0.393	0.060	-0.363	-2.555	0.065	0.060
11	-0.098	-0.031	-0.364	0.094	0.140	0.660	0.120	-0.014	1.599	0.014	-1.581	-0.364	-0.022	0.003
12	0.179	-0.121	-0.030	0.849	0.020	0.981	0.745	0.134	0.450	0.046	-0.175	-3.300	-0.016	0.006
13	0.504	0.005	0.143	0.900	-0.212	1.753	-2.578	0.147	0.196	-0.018	-0.158	-0.234	-0.220	-0.041
14	0.564	0.020	0.038	0.392	-0.398	-3.419	3.991	-0.820	-0.114	-0.039	0.047	0.232	-0.098	-0.092
Residual effect = 0.0025														
b. Phenotypic														
1	0.084	0.022	-0.049	0.014	0.018	-0.050	0.131	0.006	0.002	-0.003	0.015	-0.048	0.071	-0.039
2	0.022	0.084	-0.108	0.002	-0.008	-0.013	0.098	0.001	0.132	-0.006	-0.020	-0.177	0.020	0.000
3	0.012	0.026	-0.352	-0.004	0.004	-0.016	0.111	0.002	0.201	-0.006	-0.064	-0.003	-0.049	0.013
4	0.021	0.003	0.022	0.057	0.024	-0.091	0.210	0.007	0.076	0.003	-0.009	-0.162	0.085	-0.017
5	0.028	-0.012	-0.025	0.026	0.053	-0.060	0.161	0.007	-0.034	0.004	0.022	0.019	0.041	-0.030
6	0.014	0.004	-0.018	0.017	0.010	-0.303	0.777	0.014	-0.006	-0.001	0.017	0.045	-0.047	-0.043
7	0.013	0.010	-0.047	0.014	0.010	-0.280	0.839	0.015	0.025	-0.001	-0.003	-0.040	-0.063	-0.047
8	0.021	0.003	-0.030	0.018	0.016	-0.196	0.577	0.022	0.031	0.000	0.001	0.026	-0.016	-0.055
9	0.000	0.019	-0.125	0.008	-0.003	0.003	0.037	0.001	0.568	-0.001	-0.195	-0.113	0.020	0.008
10	0.007	0.016	-0.076	-0.006	-0.007	-0.010	0.025	0.000	0.027	-0.030	-0.011	-0.053	-0.024	0.010
11	-0.005	0.007	-0.096	0.002	-0.005	0.021	0.010	0.000	0.473	-0.001	-0.235	-0.047	0.025	0.005
12	0.008	0.029	-0.002	0.018	-0.002	0.027	0.067	-0.001	0.127	-0.003	-0.022	-0.506	0.018	0.008
13	0.023	0.006	0.066	0.019	0.008	0.054	-0.202	-0.001	0.044	0.003	-0.023	-0.035	0.262	-0.051
14	0.026	0.000	0.036	0.008	0.013	-0.104	0.310	0.009	-0.038	0.003	0.009	0.031	0.106	-0.126

Table 5a: Clustering of genotypes according to the D square analysis

Cluster	Number of genotypes	Name of the genotypes
I	11	Pol-4-4-5, BCSP-10, CO-3, NDSP-9, Pol-20-6-2, BCSP-5, IBM-95-229, RNSP-1, NDSP-10, IGSP-8, RNSP-2
II	9	IGSP-7, IGSP-6, BCSP-7, IGSP-9, IBM-95-220, IBM-95-206, BCSP-14, Tripty, S-1221
III	1	WBSP-4
IV	1	Kamala Sundari

Table 5 b: Average intra and inter cluster distance SQRT (D^2) values.

Cluster	1	2	3	4
I	24.435			
II	31.678	22.491		
III	38.798	27.539	0.000	
IV	39.034	47.575	37.907	0.000

distance value. Comparatively lower D -values are indicative of a greater genetic uniformity or *vice versa* (St. Pierre *et al.*, 1990). Tarafdar and Chatterjee (2003) also reported the genetic relationships with consistence phenotypic characters in turmeric.

In the present grouping, cultivars belonging to the clusters II and III have a lower cluster distance value and, hence, are genetically more uniform. Whereas the single cultivar, Kamala Sundari of cluster IV is quite different from the other cultivars in group II. Kamala Sundari, is quite distinct from other cultivars in the colour of the stem, leaf, leaf veins, flower and it has hairy sepals with acuminate tip, stamen as long as style and having orange tuber skin and flesh colour. The cultivars of group II and III share many similar traits. Hossain *et al.* (2000) described the significant relationship among the root diameter, tuber weight per plant and yield in sweetpotato.

Sweetpotatos is an important source of many nutrients. It contains high amount of protein, minerals, vitamins, and amino acids, although it contains virtually no fat and are low in sodium (Hall, 2003). Sweetpotato tuber

is rich in total carbohydrate but poor in protein content. Among the nutritional parameters analyzed, considerable variation was observed in dry matter, total carbohydrate, crude and soluble protein and vitamin-C. Less variation was observed in mineral composition. Red and orange varieties showed higher amount of carbohydrate than white tubers. A similar result was reported by Osumdahunsi *et al.* (2003). Crude protein in these cultivars ranged from 1.85 to 9.33 gm/100gm. Similar trends have been reported by Ravindran *et al.* (1995), Babu (1996) and recently by Osumdahunsi *et al.* (2003). Hartana *et al.* (1998) also reported that the orange-fleshed sweetpotato clones were the most potential breeding lines because of their higher carotene, dry matter, protein and carbohydrate content with high yield and resistance to scab diseases. In this study identification of such characters linked to the yield attributing factors, nutritional values and field response to sweetpotato viral diseases is valuable to the breeding programme for the genetic improvement of sweetpotato.

The moderate to high incidence of virus diseases was observed among the cultivars.

Table 5 c: Cluster means of sweet potato cultivars and contribution sixteen different morphological characters towards divergence.

Cluster	X ₁ Vine length	X ₂ Petiole length	X ₃ Lamina length	X ₄ Inflorescence length	X ₅ Pedicel length	X ₆ Flower length	X ₇ Flower Diameter	X ₈ Sepal length	X ₉ Stamen length	X ₁₀ Anther length	X ₁₁ Carpel length	X ₁₂ LAI	X ₁₃ Tuber length	X ₁₄ Tuber breadth	X ₁₅ Weight of tuber/5 plants	X ₁₆ Tuber yield (ton/ ha)
I	77.179	11.079	8.689	8.9	0.9154	3.527	2.9381	0.9572	0.9772	0.3727	1.3809	1.2909	15.879	4.368	3.6518	17.444
II	81.48	11.744	9.174	9.615	0.86	3.28	3	0.874	1.461	0.35	1.918	1.6	19.456	5.228	3.902	21.546
III	80.5	13.9	9.83	16.33	1.33	4.15	3.5	1	1.7	0.4	2.15	1.7	18.23	4.67	2.6	38.33
IV	101.83	11.27	9	14.67	1.47	5	4.55	1.47	1.05	0.5	1.1	2.2	15.27	7.53	2.63	32.9
	0	0	0	0	0	10.82	0	0	6.93	0	20.35	24.68	1030	6.49	0	29.44

The viruses most commonly detected were sweetpotato C-6 virus, SPCaLV and SPCFV. The less common ones were SPFMV, SPMMV and SwPLV. Schaefer and Terry (1976), Stobbs *et al.* (1991), Marinho and Dusi (1995), Cohen *et al.* (1997), noticed a wide range of variation in symptoms produced by the different viruses in sweetpotato. The detection of viruses in our cultivars will direct priorities for future research. This is the first time sweetpotato viruses have been reported in West Bengal, India. Although the cultivars, WBSP-4, Pol-20-6-2, S-1221, BCSP-10, BCSP-10, IGSP-8, NDSP-10 and BCSP-7 showed wide range of virus-like symptoms, no viruses were detected in them. More studies are needed to ascertain whether they are caused by viruses, and if so, the identity of the viruses.

Implications

The morphological and biochemical analyses showed some congruent groupings among the Indian sweetpotato cultivars. Inclusion of different cultivars in different groups may be a meaningful indicative of their origin or divergence from a common stock. Analysis of physical and qualitative parameters supplemented the morphological based interpretation. Attention will be put on checking the spread of the prevalent viruses among the cultivars. These studies have provided an insight into the interrelationship among twenty-two cultivars of sweetpotato and its virus diseases, which could give a new arena in the sweetpotato improvement programme.

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Table 6: Qualitative assessments of some morphological and physical characteristics of twenty-two sweetpotato cultivars.

Cultivar	Habit	Stem colour	Stem surface	Leaf margin	Leaf texture	Leaf colour	Vein colour	Base of the leaf	Apex of the leaves	Petiole colour	Sepal surface
Tripty	Annual –erect	Pinkish green	Hairy	Entire	Thin	Deep green	Light purple	Cordate	Acuminate	Greenish purple	Glabrous
IBM-90-229	Annual –erect	Green	Hairy	Lobed	Thin	Bass green	Whitish green	Cordate	Acuminate	Light pinkish green	Glabrous
WBSP-4	Annual –erect	Pinkish green	Hairy	Wavy	Thin	Purple green	Purple	Cordate	Acuminate	Deep green	Glabrous
IBM-95-220	Annual –erect	Green	Hairy	Wavy	Thin	Bass green	Whitish green	Cordate	Acuminate	Purplish green	Glabrous
Kamala Sundari	Annual –erect	Purple-green	Hairy	Entire	Thin	Deep Purple	Purplish green	Truncate	Acuminate	Purplish green	Hairy
Pol-20-6-2	Annual –erect	Green	Hairy	Pinnatifid	Thin	Purple green	Light green	Truncate	Acuminate	Light green	Glabrous
Pol-4-4-5	Annual –erect	Pinkish green	Hairy	Lobed	Thin	Purple green	Purplish green	Cordate	Acuminate	Bass green	Glabrous
BCSP-14	Annual –erect	Green	Hairy	Entire	Thin	Bass green	Light green	Cordate	Acuminate	Purplish green	Glabrous
S-1221	Annual –erect	Green	Glabrous	Entire	Thin	Deep green	Whitish green	Truncate	Acuminate	Light green	Glabrous
BCSP-5	Annual –erect	Green	Glabrous	Lobed	Thin	Bass green	Whitish green	Cordate	Acuminate	Light green	Glabrous
IBM-95-206	Annual –erect	Green	Glabrous	Lobed	Thin	Deep green	Purplish green	Cordate	Acuminate	Purplish green	Glabrous
BCSP-10	Annual –erect	Green	Glabrous	Palmate	Thin	Deep green	Purple	Cordate	Capisdate	Purplish green	Glabrous
RNSP-1	Annual –herb	Green	Hairy	Palmate	Thin	Deep green	Whitish green	Cordate	Acuminate	Light green	Glabrous
RNSP-2	Annual –erect	Green	Glabrous	Lobed	Leathery	Bass green	Pinkish green	Cordate	Acuminate	Bass green	Glabrous
IGSP-6	Annual –erect	Green	Glabrous	Palmate	Leathery	Bass green	Green	Truncate	Acuminate	Bass green	Glabrous
IGSP-7	Annual –erect	Green	Glabrous	Pinnatifid	Thin	Bass green	Purple	Truncate	Acuminate	Purplish green	Glabrous
IGSP-8	Annual –herb	Green	Hairy	Entire	Thin	Deep green	Purple	Truncate	Acuminate	Purplish green	Glabrous
IGSP-9	Annual –erect	Green	Glabrous	Palmate	Thin	Bass green	Whitish green	Truncate	Acuminate	Bass green	Glabrous
NDSP-9	Annual training	Green	Glabrous	Palmate	Thin	Light green	Purple	Cordate	Acuminate	Whitish green	Glabrous
NDSP-10	Annual –erect	Pinkish green	Glabrous	Entire	Leathery	Purple green	Purple	Truncate	Acuminate	Purplish green	Glabrous
BCSP-7	Annual –erect	Green	Glabrous	Entire	Thin	Bass green	Whitish green	Truncate	Acuminate	Bass green	Glabrous
CO-3	Annual –erect	Green	Glabrous	Palmate	Thin	Purple green	Whitish green	Truncate	Acuminate	Light green	Glabrous
Sepal tip	Sepal shape	Petal colour	Corolla eye	Filament colour	Anther colour	No. of Carpel	Ovary chamber	Style as long as stamen /longer	Tuber shape	Tuberskin colour	Tuber flesh colour
Tripty	Ligulate	LL	PP	Present	Pink	2	3	Longer	Spindle	Cream white	Cream white
IBM-95-229	Ligulate	OO	Purple	Present	White	2	3	Longer	Long thin	Deep red	Yellowish cream
WBSP-4	Ligulate	LL	PP	Present	Purple	2	2	Longer	Elliptical	CreamWhite	Yellow-White
IBM-95-220	Ligulate	LL	PP	Present	Purple	Reddish	2	Longer	Long	Carlet red	Pinkish white
Kamala Sundari	Accuminate	LL	Purple	Present	Purple	2	2	Long as stamen	Long-blunt	Orange	Bright orange
Pol-20-6-2	Ligulate	LL	PP	Present	White	2	2	Longer	Long	Pink red	White
Pol-4-4-5	Ligulate	OO	PP	Absent	Yellow	2	2	Longer	Long	Cream white	Pinkish white
BCSP-14	Ligulate	LL	PP	Absent	White	2	2	Longer	LC	Deep pink	Cream
S-1221	Ligulate	LL	PP	Present	Purple	2	2	Longer	Slender long	Yellowish pink	Whitish yellow
BCSP-5	Ligulate	OO	PP	Present	Purple	White	2	Longer	Cylindrical	Deep red	White
IBM-95-206	Rounded	OO	PP	Present	White	2	3	Longer	LSP	Cream white	Cream white
BCSP-10	Ligulate	LL	PP	Present	White	2	2	Longer	LC	Pink red	Light yellow
RNSP-1	Ligulate	Broad ovate	PP	Present	Purple	White	2	Longer	Spindle	White	Orange yellow
RNSP-2	Ligulate	OO	PP	Present	White	White	2	Longer	Oval	Light pink	Cream yellow
IGSP-6	Ligulate	OO	White	Absent	White	White	2	Longer	LE	Carlet red	Cream yellow
IGSP-7	Ligulate	LL	White	Absent	Yellow	Yellow	2	Longer	LE	Pinkish red	Cream white
IGSP-8	Ligulate	PP	Purple	Present	Purple	PP	2	Longer	LE	Oranges pink	Whitish yellow
IGSP-9	Ligulate	OO	PP	Present	Purple	White	2	Longer	LE	White	Cream
NDSP-9	Ligulate	PP	PP	Present	White	White	2	Longer	LC	Cream	Cream white
NDSP-10	Ligulate	LL	PP	Present	Purple	White	3	Longer	LS	Pinkish red	Cream white

LL: Linear lanceolate; OO: Ovate oblong; PP: Pale purple; LE: long elliptical; LC: Long cylindrical; LS: Long spindle.

Table 7: Dry matter percentage and proximate nutritional composition of sweetpotato tubers from twenty-two Indian cultivars.

Cultivar	Dry matter %	Total Carbo-hydrate gm/100	Protein (Crude) gm/100 gm (dwb)	Protein (soluble) mg/gm ⁻¹ (fwb)**	Vit.C gm/100 gm (dwb)	Femg/100 gm (dwb)	Mnmg/ 100 gm (dwb)	Cumg/ 100 gm (dwb)	Znmg/ 100 gm (dwb)
Tripty	20.13	27.75	6.13	15.77	10.88	12.0	0.65	0.25	1.60
IBM-90-229	18.23	30.60	7.46	18.48	15.99	10.5	0.50	0.75	1.50
WBSP-4	22.33	29.89	5.24	21.04	18.88	10.0	0.45	0.35	1.55
IBM-95-220	28.83	24.07	7.75	21.50	27.94	9.0	0.45	0.35	1.55
Kamala Sundari	18.50	38.4	7.79	19.71	20.39	9.0	0.70	0.40	1.45
Pol-20-6-2	24.72	37.20	7.25	11.93	25.87	14.0	0.85	0.60	1.35
Pol-4-4-5	24.53	34.28	7.13	07.15	26.18	13.5	0.95	0.75	1.50
BCSP-14	25.50	37.20	2.90	09.28	14.8	16.0	1.00	0.50	1.45
S-1221	15.62	33.03	4.92	25.90	14.3	13.0	0.85	0.45	1.45
BCSP-5	27.54	31.71	9.33	19.61	10.88	15.0	0.70	0.50	1.55
IBM-95-206	23.10	26.20	3.50	06.61	12.66	17.0	0.65	0.25	1.45
BCSP-10	23.47	33.72	1.85	09.69	16.18	15.0	0.90	0.25	1.50
RNSP-1	20.49	33.30	4.36	09.88	31.18	13.5	1.01	0.75	1.35
RNSP-2	22.27	26.69	3.24	18.70	16.94	13.0	1.10	0.25	1.45
IGSP-6	19.97	23.46	4.25	21.65	27.84	13.5	0.70	2.05	1.50
IGSP-7	20.71	24.59	4.55	19.84	12.55	14.5	0.65	0.30	1.60
IGSP-8	20.13	23.88	3.94	21.30	16.47	15.0	0.60	0.30	1.45
IGSP-9	24.62	28.10	3.50	18.87	18.43	16.0	0.90	0.35	1.50
NDSP-9	23.26	35.07	4.63	27.63	35.39	17.5	0.85	1.35	1.55
NDSP-10	22.53	26.63	5.23	18.49	14.84	17.0	1.01	0.75	1.50
BCSP-7	24.65	28.88	6.51	17.05	29.89	15.0	0.80	0.30	1.50
CO-3	24.61	24.73	3.57	16.36	12.8	15.0	0.85	0.35	1.60
SEM±	0.84	0.80	0.33	0.57	4.13	0.37	0.07	0.03	0.03
C.D. p=0.05%	2.41	1.63	0.94	1.64	8.36	1.08	0.21	0.09	0.10

*dwb : Dry weight basis, **fwb: Fresh weight basis.

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Correlation study on population dynamics of ginger soft rot inciting pathogens under different organic amendments, disease incidence and its survival in Darjeeling hill soils

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Abstract. Ginger soft rot complex disease incited by *Pythium spp.*, *Fusarium spp.* and *Ralstonia solanacearum* survived extended periods in naturally infested ginger rhizosphere soil. In pieces of organic matter or dead roots application of Farm Yard Manure (FYM) along with different locally available organics like neem cake, FYM, leaves extract of *Scima wallichi*, garlic extract and mustard oil cake were investigated the effect on the population dynamics of the pathogens. The inoculum densities were decreased markedly due to amendments of the different organics in the plots in comparison to the check plots. Analysis of variance implicated that propagule density of two fungal pathogens viz. *Fusarium spp.* and *Pythium spp.*, in the ginger rhizosphere soil steadily declined with the application of the organic extracts. The correlation matrix study on the propagule density of the pathogens at the different growth stages revealed that decreasing inoculum density of two fungal pathogens was highly significant with decreasing disease. The application of FYM with mustard cake and neem cake showed significant reduction of *Fusarium spp.* and *Pythium spp.* and population of *Ralstonia solanacearum*, respectively and increased the fresh rhizome

yield. The microscopic observation also revealed that the survival of fungal pathogens in the plant debris presented several epidemiological considerations.

Introduction

Ginger is an important commercial crop, which earns a sizeable amount of foreign exchange for the country. But presently, the outbursts of soft rot disease of ginger throw a challenge to the ginger growers, scientists and planners. Various chemicals are adopted to control the disease. The chemicals are costly and also hazardous to the environment as well as the quality of the ginger. So it is imperative to control the disease in a sustainable manner through other agencies- easily available, eco-friendly and remunerative. In this context, many organic amendments show very effectiveness to control the soil borne diseases (Dohroo *et al.*, 1994, Lazarovits, 2001). Hence, it would be very interesting and useful to study the efficacy of locally available conventional and non-conventional soil amendments to control the soft rot of ginger under degraded agro ecosystem of terrace cultivation in hilly area of Darjeeling hills for sustenance of the ginger cultivation.

Materials and Methods

Soil application of FYM (5 kg/2 sq m), alone or in combination with mustard oilcake (1kg/2sq m) and neem (*Azadirachta indica*) cake (1kg/sq m) as well as leaf extract of Chillaune plant (*Scima wallichii*) (2 kg/10 l of water) and garlic extract (250 g/ 1 l of water) for foliar spray as well as soil application was tested against the abundance of ginger soft rot disease inciting agents *Fusarium* sp., *Pythium* sp. and *Pseudomonas* sp. The natural rhizosphere population of cited microorganisms are enumerated in standard specific medium meant for. The quantitative assay of the population density of the amended rhizosphere soil is performed at sprouting, active tillering stage and at harvest of ginger. The incidence of ginger soft rot was recorded at active tillering stage by adopting 0 – 9 scale to cover all the broad symptoms. The percent disease (PDI) was calculated using the following formula:

$$PDI = \frac{\text{Total scores} \times 100}{\text{Total number of plants assessed} \times 9}$$

The correlation matrix of the population dynamics of pathogens at different crop growth stages is compared with disease severity and yield. Roots and rhizomes of ginger from the field are assayed for *Pythium* spp. by thoroughly washing seedlings in tap water. After washing the plant parts were surface sterilized with 0.1% mercuric chloride followed by washing with sterile water and cut into 2-3mm pieces. The cut pieces were rinsed in 10% KOH at 4° C overnight and after washing with 0.1N HCl the tissues were observed under microscope. The microscopic observations of the infected tissues from ginger rhizome were made to assure the presence of the fungal structure in side the tissues.

Results and Discussion

Analysis of variance showed soil amended with FYM alone or in combination with cited organics exerted significant drastic effect on the population density of *Fusarium* sp. *Pythium* sp. and *Pseudomonas* sp. and percent disease incidence of soft rot of ginger at different growth stages as compared to that of control (Table 1). In this context, FYM and mustard oil cake together induced the most inimical influence on the population dynamics of cited pathogenic organisms as well as diseases incidence. This substantiates the earlier report of Rajan and Singh (1971), Sadanandan and Iyer (1986), Toyata and Kimura (1992), Dohroo *et al.* (1997) that FYM amended soils were more fungistatic than non-amended soils. The active ingredient of organics in combination of FYM used, which may produce such amelioration effects on soil borne pathogens as reducing numbers by lysis, temporarily or permanently inactivating fungal propagules, serving food bases for antibiotic and toxic production or as the origin of inhibitory volatile substances. Moreover, the organic amendments may cause the proliferation of certain beneficial organisms resulting in detrimental influence on the growth of pathogenic organisms in ginger rhizosphere. The relative reduction of PDI was due to relative effectiveness of the organics to suppress the pathogens concerned. The results showed superiority of mustard oil cake to other organics, its intrinsic quality being more inhibitory to the pathogens (Table 1).

With the age of the crops, the population density of the pathogens increases from sprouting of mother rhizomes to active tillering of pseudo stem and then declines at the harvesting of daughter rhizome. This suggests that initial decomposed products of organics are beneficial to the pathogenic organisms while the advanced products are inhibitory. Moreover, the advanced decomposed products encourage more natural antagonist to control the cited

Table 1: Relative abundance of ginger soft rot inciting pathogens, disease incidence and rhizome yield under different treatments.

Treatment	Fusarium (CFU X10 ³)			Pythium (CFU X10 ³)			Pseudomonas (CFU X10 ³)			%Disease Infection	Yieldt/ha
	S1*	S2	S3	S1	S2	S3	S1	S2	S3		
Control	63.16a	109.78a	102.93a	60.48a	85.02a	70.85a	135.75a	149.11a	128.33a	79.62	6.0
FYM	33.41u	98.02u	63.81u	24.24c	79.60ab	56.57b	88.46c	90.12bc	80.25cd	54.48	8.3
FYM+ Garlic Extract	28.91uà	95.79u	61.20u	19.92e	70.86b	53.47bc	110.53b	104.32b	88.91c	54.16	9.3
FYM+ NeemCake	22.03fd	52.39c	32.82c	41.59b	56.81c	50.50bc	66.08e	56.18d	69.44d	49.07	10.0
FYM+ChillauneLeave Extract	18.24d	47.97h	23.86f	25.59c	54.28c	45.22cd	14.85b	146.46a	113.69b	43.51	10.75
FYM+Oil cake(Mustard)	16.23d	38.45d	4.61c	23.89c	43.58d	39.76d	75.46d	75.64c	82.06e	37.96	13.25

S1, S2 and S3 denote sprouting, active tillering and harvesting stage of gingers. Figures represented by same letter are not significant by DMRT.

pathogens. Additionally, rhizosphere effects as discussed by Ketznelson (1965), affect the soil borne plant pathogens differently under different growth stages. At the later stage of growth, root may exudates more oleresin inhibitory to the growth of pathogenic organisms. It is also evident that high nitrogen product mixture may increase the free ammonia and nitric acid in soil, which are toxic to some of the pathogens (Lazarovits, 2001).

Neem cake in combination with FYM suppresses more *Pseudomonas* cells than that of mustard oil cake as in case *Fusarium* and *Pythium*. Neem cake may elaborate some anti-bacterial volatile substances, which destroy the viable bacterial cells. Lazarovits (2001) explains that organic amendments reduce the plant pathogens and some of the beneficial organisms are found to increase which are potential bio-control agents.

The highest rhizome yield was recorded under the influence of FYM and oil cake followed by those of chillaune leaves extract, neem cake and garlic extract, respectively. The sequential influence of treatments of yield of ginger is in accordance with the relative influence of respective treatments on the soft rot disease incidence. Moreover, FYM improves the overall soil conditions to support the better establishment of ginger which inturn, impart better resistance toward the soft rot disease, resulting good yield. Results thus establish that mustard oil cake and chillaune leaves in combination with FYM can effectively be used in ginger soft rot management programme in hilly areas of Darjeeling Himalayan region.

In the correlation studies on the population counts of three pathogenic organisms the results reveal that there is a positive interaction on the population of *Fusarium* sp. and *Pythium* sp. at the different growth stage of the plants and the inoculum density of these two fungal pathogens would be accelerated to significantly very high level with a strong relationship between these two pathogens at the active tillering stage of the crop. The severity of soft rot disease positively correlates with the propagule

Table 2: Analysis of correlation coefficient with population density of the soft inciting pathogens, disease incidence and yield of ginger.

Fu-S1	Fu-S2	Fu-S3	Py-S1	Py-S2	Py-S3	Ps-S1	Ps-S2	Ps-S3	PDI	Yield	(t/ha)
Fu-S1	1.000										
Fu-S2	0.829	1.000									
Fu-S3	0.968	0.935	1.000								
Py-S1	0.770	0.341	0.613	1.000							
Py-S2	0.857	0.976	0.928	0.440	1.000						
Py-S3	0.967	0.887	0.963	0.730	0.930	1.000					
Ps-S1	0.687	0.603	0.661	0.372	0.592	0.633	1.000				
Ps-S2	0.526	0.383	0.454	0.302	0.411	0.455	0.948	1.000			
Ps-S3	0.629	0.355	0.516	0.504	0.389	0.521	0.927	0.963	1.000		
PDI	0.987	0.845	0.963	0.779	0.877	0.988	0.687	0.511	0.602	1.000	
Yield(ton/ha)	-0.904	-0.895	-0.914	-0.644	-0.956	-0.978	-0.633	-0.476	-0.494	-0.942	1.000

^a>0.811 are significant at 5% level of significance and ^b>0.917 are significant at 1% level of significance.

pressure of *Fusarium* sp. and *Pythium* sp., whereas, the population counts of *Pseudomonas* sp. does not show the relationship with PDI. However, with the yield of rhizome, it was significantly negative (Table 2). Thus, the active increase in population of two fungal pathogens result high intensity of soft rot disease of ginger in the field

Propagules of *Pythium* sp. are recovered from the roots and rhizomes at harvest. Oospore and chlamydospores are the most frequent form of over wintering propagule of *Pythium* isolated from the root tissues. Direct microscopic examination shows that both oospore and chlamydospore are found in association with root tissues, which are left in the field and may survive as dormant phase in the soil organic matter. It is reported that oospore of *Pythium aphanidermatum* are the sole survival structures in naturally infested soil (Burr and Stranhellini, 1973). The formation zoosporiums are also very common in the tissues of the infected rhizome. Soil samples taken in the rhizosphere of ginger plant, tissues from roots and rhizome of infected plants may contain mycelial fragments and conidia, which could give rise to colonies on a dilution plate. The occurrence of *Fusarium* sp. and *Pseudomonas* sp. are very wide spread in the infested soil. The bacteria do not produce survival structures that can be readily isolated from the soil and plant sample, which incite the infection.

Implications. Results thus establish that mustard oil cake and chillaune leaves in combination with FYM can effectively be used in ginger soft rot management programme in hilly areas of Darjeeling Himalayan region and lead to reduce the soil population of the pathogens.

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Selection of sweetpotato with high protein and/or low trypsin inhibitor activity

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Abstract. Low content of protein and the presence of anti-nutritional factor ‘trypsin inhibitor’ diminish the nutritional value of sweetpotato (*Ipomoea batatas* L.) as animal feed. Efforts have been made to develop sweetpotato with high content of protein and/or low activity of trypsin inhibitor (TIA). Crude protein content and TIA of more than 800 breeding lines of sweetpotato were measured during 5 seasons from 1998 to 2002. Seven lines were selected as low TIA (14 to 120 TUI/mg DW) and 15 lines as high protein (26.1 to 46.6 mg/g DW), when compared to a standard variety ‘Shiroyutaka’ (TIA: 148 TUI/mg DW, protein content: 17.4 mg/g DW). There was a strong positive correlation between protein content and TIA ($r=0.856^{**}$). However, Q94128-1 (TIA: 6 TUI/mg DW, protein content: 26.8 mg/g DW) and KNF94225-13 (TIA: 59 TUI/mg DW, protein content: 32.0 mg/g DW) had high contents of protein but low TIA. Activity staining of trypsin inhibitor in the proteins extracted from these two lines on polyacrylamide gel revealed lack or less activity of trypsin inhibitor.

Introduction

About 44% of the world’s annual sweetpotato production is used as animal feed (FAO, 2001). It is rich in nutrients, such as starch, sugars, vitamins and minerals (Ravindran *et al.*, 1995, Okuno *et al.*, 1998). The compounds such as polyphenolics, β -carotene, anthocyanins, vitamins, fibre and jalapin in sweetpotato have many beneficial dietary functions (Yoshimoto,

2001). From the nutritional point, sweetpotato may also be a good material for animals. However, some shortcomings diminish its nutritional value as animal feed. One of these is the low protein content, normally 4.5-7 % of dry matter (Purcell *et al.*, 1972). The other is the trypsin inhibitor (TI), which reduces protein digestibility in uncooked roots (Yeh and Bouwkamp, 1985).

The major sweetpotato protein in roots, sporamin, accounts for 80% of total soluble protein (Maeshima *et al.*, 1985). Sporamin is one form of TI in sweetpotato confirmed by recombinant DNA experiments (Yeh *et al.*, 1997). The level of trypsin inhibitor activity (TIA) positively correlates with soluble protein (Bouwkamp *et al.*, 1985) and crude protein content (Zhang *et al.*, 1998). Therefore, development of a sweetpotato variety with high protein and low TIA is a big challenge.

There are cultivar differences both in protein contents (Purcell *et al.*, 1972) and TIA (Wang and Yeoh., 1996, Zhang *et al.*, 1998, Yeoh *et al.*, 2000). The rapid method of estimating TIA (Yeoh *et al.*, 2000) helps to select a good number of breeding lines with low TIA. High protein content, low TIA, as well as a high dry matter yield will make sweetpotato more attractive as a source of animal feed. In this report, we present some sweetpotato lines with high protein content and / or low TIA, which were selected from more than 800 breeding lines during 1998-2002. TIs from high and low lines were compared using SDS-PAGE. Partially purified TIs were used as standards.

Materials and Methods

Plant materials. More than 800 breeding lines or cultivars of sweetpotato were used for the analysis between 1998-2002. These breeding lines were obtained after crossing more than 150 breeding lines or cultivars.

Experimental design. Twenty plants for each lines were planted in two rows at a density of 38100 plants/ha. NPK fertilizer was applied (600 kg/ha) (1998-1999: N-P₂O₅-K₂O=6-8-12, 2000-2002: 8-12-20). The crop was allowed to grow for 5 months. Twenty-two lines selected until 2001 were tested again in 2002.

Preparation of sweetpotato flour and crude extract. Six freshly harvested roots for one line were washed, shredded and mixed. A 100g sample was lyophilized and the dried sample ground in a blender for 1 min. to pass through a 212 µm sieve. The resulting flour (50mg) was extracted in 2 ml 50 mM Tris-HCl buffer (pH8) in 2 ml micro-centrifuge tubes. Samples were vigorously shaken for 10 min. followed by centrifugation at 13,000 rpm at 4 °C for 15 min. The supernatant was then used for trypsin inhibitor assay and soluble protein determination.

TIA estimation. TIA was measured according to Yeoh *et al.* (2000). TIA was expressed as TUI (trypsin unit inhibited) per 1 mg dry sample (Zhang *et al.*, 1998). Trypsin units were defined as an A₄₁₀ increase of 0.01 under the assay conditions where trypsin and substrate solution were mixed.

Protein determination. Protein contents were estimated from total N analyzed by Kjeldahl method. Two g rammes of sweetpotato flour was used for the analysis. Soluble protein was determined by using the BioRad protein assay reagent.

Sweetpotato TI purification. Ten kilogrammes of 'Shiroyutaka' roots stored for six month was used for TI purification. Roots were washed, shredded and homogenized with two

volumes (w/v) of water in a homogenizer for 100s. The homogenates were filtered through two layers of mesh and centrifuged for starch elimination at 8000 × g for 10 min. The resultant supernatant was lyophilized and about 500 g of the crude TI powder was obtained. They were stored at -80 °C until use. For further purification, 75g of the lyophilized powder were dissolved in 1.5 l of 100 mM Tris-HCl buffer (pH 7.9). The precipitates from 30-60% ammonium sulphate saturation of this solution were dissolved in 100 ml of 100 mM Tris-HCl buffer (pH 7.9). After dialysis against the same buffer they were loaded on to trypsin affinity column. The active portion was collected according to Hou and Lin (1997). They were dialyzed against water and lyophilized.

Protein and TI activity staining on SDS-PAGE gels. SDS-PAGE was carried out using commercially available precast gel systems (Invitrogen Corp., Carlsbad, CA, USA). Tris-Glycine gels (gel concentration of 14 %) and Nupage gels (gel concentration of 10 %) were used with Tris-Glycine buffer and MES buffer as the electrophoresis buffer, respectively. Coomassie brilliant blue R250 was used for protein staining. TI activity staining was carried out according to Hou and Lin (1998).

Results and Discussion

Selection of high protein and/or low TIA lines. Crude protein contents of more than 800 sweetpotato breeding lines were analyzed during 1998-2001. The protein content varied from 8.0 to 54.0 mg/g DW. The protein content of standard variety, 'Shiroyutaka' was from 17.0 to 21.4. Twenty-two lines selected so far were tested again in 2002 for protein content. Fifteen lines were finally selected as high protein (26.1 to 46.6 mg/g DW) (Table 1). The protein content of the line Q98174-11 (46.6 mg/ g DW) was the highest among the selected 15 lines, but was much lower than the protein content (91.4 mg/g DW) of varieties from North Carolina root collection (Purcell *et al.*, 1972). Generally, an increase in the rate of applied N to plantings of

sweetpotato leads to an increase in root N content (Purcell and Walter, 1982). Low protein level of our lines may be due to low N level in the breeding field. Although we found negative correlation between crude protein content and dry matter (-0.456) or dry matter yield (-0.405) (Table 2), three lines were found to have higher dry matter content (36.3 to 39.1 %) than 'Shiroyutaka' (Table 1).

Seven lines were selected as low TIA (14 to 120 TUI/mg DW). Most of the lines selected had higher dry matter (31.1 to 40.3 %) than

'Shiroyutaka', although dry matter yield of all lines were lower than 'Shiroyutaka' (Table 1). Over all, TIA showed a negative correlation with dry matter content (-0.268) and dry matter yield (-0.215) (Table 2).

The analysis of 244 breeding lines in 2001 showed that there is very high correlation (0.856) between crude protein content and TIA (Table 2). Most of the fifteen high protein lines selected were with high TIA, and seven low TIA lines selected had low protein content (Table 1). However, two lines, Q94128-1 (TIA:

Table 1: Selected sweet potato breeding lines with high protein or low TIA.

	Lines	Crude protein (mg/gDW)	TIA (TUI/mg DW)	Dry matter content (%)	Dry matter yield (t/ha)
High protein	Q90142-22	31.9	632	35.7	11.7
	Q93017-5	26.7	327	32.1	9.5
	KNF93111-4	28.7	379	28.2	10.5
	Q94128-1	26.8	6	22.9	6.5
	KNF94225-13	32.0	59	19.2	4.1
	Q97260-8	43.8	661	30.7	8.5
	Q97236-4	35.9	435	28.5	5.9
	Q98106-5	28.5	327	35.4	12.7
	Q98158-4	27.9	403	39.1	8.2
	Q98158-12	26.1	150	34.3	10.7
	Q98160-7	37.8	462	33.4	5.1
	Q98161-4	36.1	319	37.6	7.8
	Q98161-5	37.8	624	36.3	8.7
	Q98174-11	46.6	579	22.7	8.1
	Q95175y2	33.5	418	36.1	9.2
Low TIA	Q94279-2	15.5	120	39.5	12.1
	Q95180-3	15.2	31	39.2	12.9
	Q97106-9	11.6	36	40.3	10.3
	Q97106-58	14.4	14	31.1	8.4
	Q98082-3	15.4	74	39.1	10.2
	Q98082-10	15.6	85	37.3	10.8
	Q98097-4	16.0	88	39.4	12.4
Standard	Shiroyutaka	17.4	148	36.2	13.6

Table 2: Correlation between some important characters for feeding purpose.

0	TIA	Dry matter content	Dry matter yield
Crude protein	0.856**	-0.456**	-0.405**
TIA	-	-0.268**	-0.215**

** : Significant at p<0.01 %. Data used were from 244 breeding lines in 2001.

6 TUI/mg DW, protein content: 26.8 mg/g DW) and KNF94225-13 (TIA: 59 TUI/mg DW, protein content: 32.0 mg/g DW) had high content of protein and low TIA (Table 1).

Partial purification of TIs by trypsin affinity column. The purification step is summarized in Table 3. There were 3 major bands of 33 kDa, 22 kDa and 21 kDa in purified TIs as well as the crude extract, corresponding to trypsin inhibitor bands. However, the TI activity spots for 22 kDa and 21 kDa bands could not be distinguished.

Cultivar differences of TIs analyzed on SDS-PAGE. High TIA lines showed 2 forms of strong trypsin inhibitor bands compared to 'Shiroyutaka', corresponding to purified 33 kDa and 21-22 kDa bands, while low TIA lines lacked or had weak trypsin inhibitor bands compared to 'Shiroyutaka'. Q94128-1 (high protein and low TIA line) completely lacked trypsin inhibitor bands. The intensities of the two trypsin inhibitor bands showed positive correlation with TIA measured. Wang and Yeh

(1996) also detected 2 forms of trypsin inhibitor bands in their experiments.

Effect of pepstatin. Hou *et al* (2002) reported that sweetpotato proteinaceous TIs were degraded by an endogenous aspartic type protease. To determine whether there was any influence from endogenous proteases during sample preparation, measurements were repeated on four high protein lines with high TIA (Q90142-22, Q93017-5) or with low TIA (Q94128-1, KNF94225-13) and one middle TIA line 'Shiroyutaka', with and without pepstatin A (an aspartic type protease inhibitor). The levels of TIA as well as soluble protein contents measured did not show any difference in all the 5 lines, with and without pepstatin (Table 4). This was further confirmed on SDS-PAGE (reduced and heated condition) analyzed by Nupage system where separation and detection of protein bands were more sensitive than Tris-glycine system. The molecular weight of purified TIs was 23 kDa on this system. Protein profiles including 23 kDa TI which were extracted with 40 μ M,

Table 3: Purification of sweetpotato TIs procedure.

Procedure	Total protein (mg)	Total activity (TUI)	Specific activity (TUI/mg protein)	Yield (%)	Ratio
Crude extraction	2447	36300000	14838	100	1.0
Ammonium sulphate precipitation (30-60%)	1343	30100000	22421	83	1.5
Trypsin affinity column chromatography	94	17080000	180910	47	12.2
Dialysis	66	14560000	221109	40	14.9

Starting material was 75 g of dried sweetpotato extract (equivalent to about 1.5 kg of raw material).

Table 4: TIA and soluble protein contents of crude extract containing 0, 40 and 400 μ M of pepstatin.

Lines	TIA level	TIA (TUI/mg DW)			Soluble protein (mg/gDW)		
		Pepstatin (μ M)			Pepstatin (μ M)		
		0	40	400	0	40	400
Q90142-22	High	454	491	-	11.3	11.4	-
Q93017-5	High	301	311	-	9.2	9.3	-
Q94128-1	Low	5	10	25	11.1	11.3	11.5
KNF94225-13	Low	57	63	-	12.6	11.9	-
Shiroyutaka	Middle	144	147	-	6.4	7.2	-

400 µM pepstatin or without pepstatin did not show any difference. These results showed that endogenous protease degradation of TIs and other soluble proteins at least by aspartic type did not occur during the sample preparation. Instead of 23 kDa TI, a lot of bands of relatively high molecular weight were seen in Q94128-1 and Q94225-13, while 23 kDa TI were predominant in 'Shiroyutaka' and Q90142-22. In conclusion, we were able to select Q94128-1 and Q94225-13 as lines with high protein content and very low TIA after screening more than 800 lines. These lines could be further developed into a good source material for animal feed as well as human consumption.

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Nitrogen fertilizer application timing in 'beauregard' sweetpotato

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Abstract. Although sweetpotato storage root production is acceptable without supplemental nitrogen (N) fertilization, yields are only a fraction of the yield potential for certain cultivars. Incremental rates of fertilizer N application generally result in proportional increases in storage root yield up to a certain level of N. In certain situations, the addition of fertilizer N does not elicit any yield response. This lack of yield response to a range of fertilizer N is attributed to several factors including microorganism activity, differences in N mobilization and immobilization, leaching, dinitrification, volatilization, residual N, cultivar effects, and application timing. Application timing, including split applications may increase N use efficiency and possibly achieve yield response with added N. Evaluation of the response of 'Beauregard' to seven application timing treatments (50 kg·ha⁻¹ pre-plant, split [25 kg preplant+25 kg 28 days after transplant, DAT], 21, 28, 35, and 45 DAT) indicate that split application had the highest U.S. No. 1 storage root yield, resulting in 25% and 38% increase over pre-plant and 0 N applications, respectively. This was followed by 21 DAT (20%, 33%) and 28 DAT (3.4%, 9.8%). Applications at 35 and 45 DAT generally resulted in yield reduction (-10%, 8%) and (-32%, -9%), respectively. The results show that application timing suggests a more efficient use of N fertilization in 'Beauregard.' Application beyond 28 DAT generally results in yield reduction. The results provide growers with management options that increase fertilizer N efficiency.

Introduction

Nitrogen (N) fertilizer is an integral component of sweetpotato production and efficient management of this nutrient is prerequisite to the sustained commercial production of sweetpotatoes in certain production systems. A certain amount of nitrogen is necessary for shoot development and photosynthetic activity required for the growth of storage roots (Kays, 1985). Insufficient nitrogen can reduce yield potential of a sweetpotato crop. On the other hand, excessive nitrogen application does not increase yield and represents unnecessary waste of resources as well as potential source of contamination of surface and ground waters.

The objective of nitrogen management is to maximize the use of the nutrient and minimize potential leaching and possible contamination of surface and ground water. This requires evaluation of nutrient needs, inventory of nutrient supply, as well as assessment of nutrient balance.

Split applications of nitrogen fertilizers may increase N use efficiency (Guertal and Kemble, 1997). Fertilizer N (18 kg ha⁻¹) recovered in foliage and storage roots is maximum when applied 6 and 12 weeks after planting, respectively (Hill and Bacon, 1984). This information suggests that either post-plant or split applications may increase N utilization efficiency. Sweetpotatoes sidedressed 21 days after transplant (DAT) with 50 kg ha⁻¹ N yields the highest percent of U.S. No. 1 grade roots (Mulkey *et al.*, 1994). On the other hand, supplemental N application

(30 kg ha⁻¹ applied preplant) 40 DAT results in reduced yield (Miller and Covington, 1982). Currently, the recommended application timing for nitrogen in Louisiana is either preplant or as side-dress 25-30 DAT (Boudreaux, 1999).

Materials and Methods

The experimental trials were conducted in Chase, LA on Gilbert silt loam (Gilbert series: fine-silty, mixed, thermic Typic Glossaqualfs). Randomized complete block designs were used for two planting dates (PD), each with four replications. The following timing treatments (TT) were used: 50 kg ha⁻¹ pre-plant N, split [25 kg preplant + 25 kg 28 days after transplanting (DAT)], 21, 28, 35, and 45 DAT. The two planting dates were 4 June 2003 and 11 June 2003.

The plots were irrigated with 2.5 mm after transplanting. Rainfall during the growing season was more than 370 mm. Hand weeding was conducted whenever necessary. Plots were harvested after 105 days and the storage roots were graded and weighed into U.S. No. 1 (5.1 to 8.9 cm and 7.6 to 22.9 cm length),

canner (2.5 to 5.1 cm in diameter and 5.1 to 17.8 in length), and jumbo (larger than both groups but marketable). Due to the absence of interaction between planting dates and timing treatments, data from both tests were combined and subjected to analysis of variance (ANOVA) using GLM procedures of SAS (SAS Inst., Cary, N.C.).

Results and Conclusions

There were differences detected among the economically important U.S. No. 1 yield grade for the first planting date ($P=0.04$, data not shown). No differences were detected in the second planting date. The combined data shows that split application ($P=0.18$) had the highest U.S. No. 1 yield at 35 mt ha⁻¹, followed by applications at 21 (33 mt ha⁻¹), 28 (27 mt ha⁻¹) DAT, and preplant (26 mt·ha⁻¹) (Figure 1). Partial budget analysis shows that a grower will gain 32% revenue using split vs. preplant fertilizer N application. Split application potentially represents an approach in increasing N fertilizer efficiency.

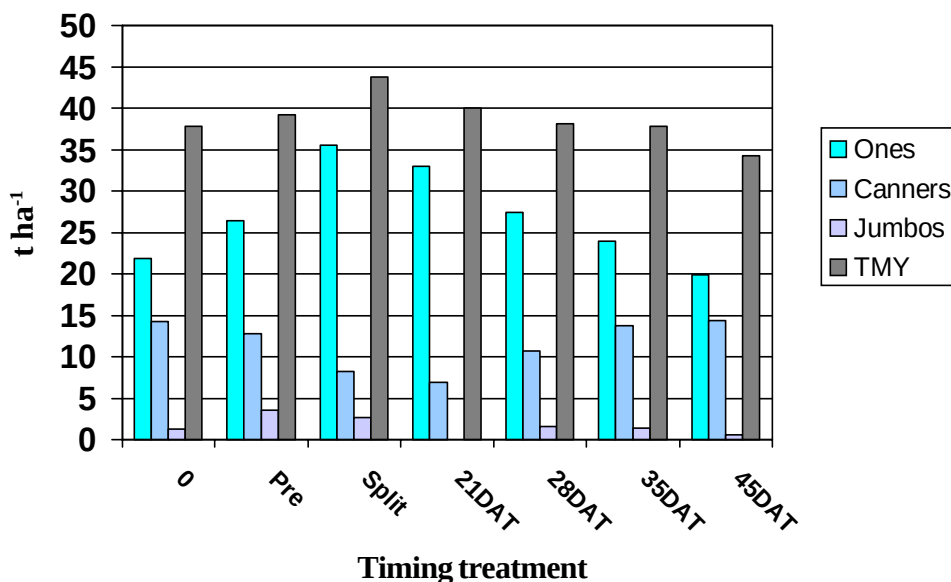


Figure1: Yield response of "beauregard" sweetpotato to nitrogen timing treatment, combined data, Chase, La, 2003.

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Implication of variation in aggressiveness of *Phytophthora infestans* (Mont.) de Bary isolates found in Kenya to potato production

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Abstract. A survey was carried out to determine the incidence and severity of late blight in four major growing potato districts. *Phytophthora infestans* isolates were found to have varying levels of aggressiveness as indicated by their reaction on tubers and detached leaves. The variability of ten different isolates of *P. infestans* was evaluated by their ability to cause disease on both detached leaf and tubers of different potato genotypes. Isolate 023 had the largest lesion diameter of 35.67mm on leaves of Kerr's Pink variety and this was significantly ($P \leq 0.05$) higher than all the other lesion diameters recorded on other isolates. Isolate 032, with a lesion diameter of 13.33mm, was the only isolate regarded as virulent on the leaves of variety Kenya Sifa. There were no isolates regarded as virulent on variety Kenya Rutuku. On tuber rot, isolate 008 was the most virulent with a diameter of 16.04mm. Isolate 035 was considered least virulent with a mean diameter of 10.04mm. Isolate 008 was the most virulent isolate with a diameter of 16.04mm. Cultivation of some popular varieties like Kerr's Pink has become impossible, as the variety is highly susceptible to the disease due to the emergence of more aggressive strains. These developments also imply that the late blight management has to be broadened to include tubers reactions to *P. infestans* in order to avail farmers varieties that meet their requirements.

Introduction

Potato is a major food crop in Kenya with an annual production of 500,000 tonnes on acreage of 106,000 ha (Ng'ang'a *et al.*, 2001). Late blight of potato caused by *Phytophthora infestans* is the most important single factor influencing potato production in Kenya and causes significant yield losses (Olanya *et al.*, 2001). For the last sixty years, the search for potato varieties with high yields, resistance to late blight, good agronomic traits and acceptable post harvest qualities was of high priority in the potato programme (Lung'aho *et al.*, 1997). Numerous potato varieties have gone through the breeding programme and have been released to the farmers based on their tolerance to late blight. However, despite cultivation of varieties with resistance to late blight, the disease continues to devastate the crop. At times when the rainfall is high coupled with cool temperatures, the disease can be extremely high even on the most tolerant varieties leading to complete loss of the crop.

The prevalence of late blight epidemics in Kenya has prompted efforts to study the structure of this fungus. The characterization of the fungus has revealed that it is of the mating type A1 (US-I-clonal lineage) based on restriction fragment length polymorphism (RFLP) (Vega-Sanchez *et al.*, 2000). Varying sensitivity to metalaxyl has also been reported

(Olanya *et al.*, 2001). Similarly, different abilities to produce oospores, which are an important character in evolution of diverse strains of the fungus, have also been reported (Hohl, 1998). The population changes have resulted in reduction of crop yields and harvested crop losses due to tuber rots. These events have prompted the efforts to carry out this study to determine the variability of aggressiveness of *P. infestans* isolates from major potato growing areas. In addition, information of the responses of potato cultivars to the *P. infestans* could determine the potential impact of a new pathogen population on potato production.

Materials and Methods

Survey for late blight incidence and severity.

Four major potato growing districts were visited in August-September 2001 in order to determine the incidence and severity of late blight. Incidence was scored as the general number of plants showing symptoms in a field while severity was scored as the percentage total foliage affected by blight.

Sample collection and laboratory isolation of *Phytophthora infestans*. Samples of potato leaves infected with late blight pathogen were collected from major potato growing areas of Kenya. This was done in Nyandarua and Nakuru districts on 6-8th August 2001, a total of 54 samples were obtained. Meru area was covered in September 2001, with 20 samples being collected. Potato leaf samples infected with late blight were obtained in fields 5-10 km apart. The samples were put in polythene bags, carefully labeled and placed in a cooler box to maintain freshness and to keep the pathogen alive. The samples were transported to the Plant Pathology Laboratory at the National Research Laboratory (NARL) for isolation of the pathogen.

Laboratory isolation. Isolation was done using the procedures described by Forbes (1997). Infected leaf sections were washed with tap water to remove soil particles, surface

sterilized in alcohol for five minutes and then with 5% calcium hypochlorite for 5 minutes and finally rinsed with four changes of sterile distilled water.

Meanwhile potato tubers were washed and dried to remove excess water and flamed in alcohol. Using a sterile knife, sections of approximately 2 mm were obtained from the tubers. The potato slices were placed in sterile Petri-dishes lined with sterile moistened blotter. The leaf sections were slotted under the potato slice and the set up left for a period of 4-7 days to allow the fungus to grow through the potato slice. Once there was substantial mycelial growth, mycelia from the surface were aseptically transferred to selective V8 media (Forbes, 1997). The plates were incubated at 15-20° C for 10 days. Isolations were repeated until pure cultures were obtained. A total of 40 isolates were obtained.

Storage of cultures. Molten selective V8 medium was prepared and poured in universal bottles placed at an angle to form slants. Each pure isolate was allowed to grow to cover the surface of the slant after which the cork was tightened and stored at 4°C. Little mycelia were obtained periodically for sub culturing as required.

Variation in aggressiveness of *P. infestans* as indicated by their abilities to cause pathogenicity on detached leaves. Pathogenicity tests were carried out in 4-6 weeks time when the host plants were ready for inoculation. Five potato varieties, namely Tigoni, Kenya Sifa, Kenya Mavuno, Dutch Robyn and Kerr's Pink with varying sensitivity to late blight were used. Leaves of the test plants were detached and washed with sterile distilled water for about 20 minutes and blotted with paper towels to remove excess moisture. The leaf bases were covered with cotton wool to avoid desiccation.

The leaves were placed upside down on 9cm plastic Petri dishes containing moistened filter paper. Sporangial suspensions obtained from actively growing cultures were adjusted

to 10,000 sporangial/ml. Three drops of 10 μ l of the sporangial suspension were applied to the mid-rib. The experimental design was complete random design (CRD) with each treatment replicated four times. Each experiment was repeated three times. Incubations were done at 17-20°C for 7 days. The diameters of lesions were measured. An isolate was regarded as being virulent if the lesion diameters were more than 10mm. The data were pooled and subjected to analysis of variance using the SAS Programme (SAS, 1997).

Variation in aggressiveness of *P. infestans* as indicated by their abilities to cause tuber rot.

Tuber rot studies using isolates collected across Kenya during the year 2001 were also performed. The method of inoculation was adopted from Peters and Platt (1999). The tubers used in the month of December 2001 had been harvested during the month of October in the same year. The tubers were stored at room temperature (18-23°C). The isolates had been previously subcultured on V8 and stored at 4°C. The experimental design was complete random design (CRD) with each treatment replicated three times. Each experiment was repeated three times. The isolates were allowed to grow for 10 days at 15°C on V8. Sterile distilled water was added to cultures and the mycelial growth scrapped slowly using a glass rod. Inoculum was diluted to concentration of 10,000 sporangia/ml using a haemocytometer. The inoculum was allowed to stand at 10°C for 1 hour to encourage release of zoospores prior to use in tuber inoculations. Tubers of different varieties (Tigoni, Asante, Dutch Robin, Kerr's Pink, Kenya Sifa and Kenya Mavuno) were used in this experiment. The tubers had been harvested a month prior to inoculation. The medium sized tubers (2 inches in diameter) were washed gently to remove adhering soil and punctured at the bud end using a cork borer. The potatoes were dipped in a suspension of individual strains of *P. infestans* for 3 minutes. The tubers were incubated in darkness at 15°C for 21 days in clear plastic

paper bags on which holes had been punctured to allow air circulation. After three weeks, the tubers were cut longitudinally and the length of tuber necrosis measured. The data were pooled and subjected to analysis of variance using the SAS Programme (SAS, 1997).

Results

Incidence and severity of late blight. Results of disease levels are shown in Table 1. The incidences and severity ranged between 10 - 85.5% and 5 - 91%, respectively. Nakuru district had the highest disease pressure while Meru had the lowest.

Studies on variation in aggressiveness of *P. infestans* on detached leaves. Results of aggressiveness of isolates on detached leaves are shown in Table 2. Different isolates expressed varying degree of aggressiveness on different cultivars. With the exception of isolates 028 and 029, the rest were very aggressive on variety Kerr's Pink. Isolate 023 had the largest lesion diameter of 35.67mm on Kerr's Pink and was significantly ($P \leq 0.05$) higher than all the lesion diameters recorded caused by other isolates. Isolate 032 with a lesion diameter of 13.33mm was the only virulent isolate on variety Rutuku. There were no virulent isolates on variety KP 90131.10. Isolates 023, 028, 034, 035 and 047 were virulent on Tigoni. Overall, isolate 023 caused the largest mean lesion diameter of 19.20mm, while 029 exhibited the least virulence with a mean diameter of 3.13mm.

Table 1: Incidence and severity of late blight in July 2001.

	Incidence (%)	Severity (%)
Kiambu	65	48
Nyandarua	65	54
Nakuru	85.5	815
Meru	-	5
Mean	66.3	46.8

Table 2: Lesion diameter (mm) on detached leaves different potato genotypes caused by varying isolates of *P. infestans*.

Isolate	Kerr's Pink	K. Sifa	K. Mavuno	Tigoni	D. Robyjn	Mean
008	11.00 d	1.00 d	6.67 ab	5.67 ef	6.00 d	6.07 c
023	35.67 a	9.00 b	5.67 b	10.33 cd	35.33 a	19.20 a
028	5.67 e	1.67 d	1.33 d	11.67 c	3.67 ef	4.80 d
029	3.67 e	3.67 d	1.00 d	4.67 ef	2.67 ef	3.13 d
032	10.33 d	13.33 a	8.67 a	7.00 e	11.33 c	10.14 b
034	24.00 bc	2.67 d	3.33 c	20.67 a	17.33 b	13.40 b
035	25.00 b	2.33 d	7.67 a	17.33 b	11.33 c	12.73 b
036	10.33 d	8.33 b	2.00 d	5.00 ef	7.67 d	6.68 c
047	26.67 b	8.33 b	2.00 d	13.67 c	24.00 a	14.93 b
Mean	19.93	5.59	4.26	10.67	13.15	
LSD	2.67					
CV %	20					

Greater than 10.00 mm are regarded as being virulent.

Table 3: Lesion diameter (mm) on tubers of different potato genotypes caused by varying isolates of *P. infestans*.

Isolate	Kerr's Pink	K. Sifa	K.Mavuno	Tigoni	D. Robyjn	Asante	Mean
008	18.5a	16.75a	20.00a	17.25ab	15.75a	8.00c	16.04ab
014	12.00b	13.25bc	15.50b	14.00bc	15.75a	13.00ab	13.92bc
023	16.75a	15.00ab	15.25b	14.25bc	14.75a	14.25a	15.04ab
029	15.50a	17.00a	20.00a	17.00ab	9.25b	15.75a	17.75a
032	14.25bc	14.50ab	14.25b	20.25a	12.00ab	12.00b	15.54ab
034	11.50c	12.25bc	11.50bc	17.50ab	10.25b	15.75a	13.13bc
035	10.00d	10.00cd	13.75b	9.25d	11.00b	6.25c	10.04c
036	15.00b	13.50bc	16.25b	13.75bc	15.00a	15.50a	14.83ab
047	15.50a	11.75c	14.25b	15.75b	11.00b	9.25b	12.92bc
Control	0.88e	0.88e	0.88cd	0.88e	0.88c	0.88d	0.88
Mean	12.99	12.49	13.01	13.99	10.68	11.01	
LSD	3.5						
CV %	46.1						

Means in the same column with same letter not significantly different.

Variation in aggressiveness of *P. infestans* on tubers. Results on tuber effect on aggressiveness of isolates is shown in Table 3. Isolate 029 was the most virulent isolate with a diameter of 17.75mm. Isolate 035 with a mean diameter of 10.04mm was the least virulent.

Discussion and conclusion

The history of late blight in Kenya dates as early as the turn of the previous century where the pathogen appears to have been introduced with the introduction of potato crop. The disease incidences and severity

Table 4: Relationship between reaction of isolates on leaves and on tubers.

	Correlation factor	($P \leq 0.05$)
Leaf lesion vs Tuber rot	0.0034	Ns

The correlation value between pathogenicity on leaves and tuber rot was positive but not significant at ($P \leq 0.05$) (Table 4).

ranged between 10-90% and 5-85.5%, respectively. Nakuru district had the highest disease pressure while Meru had the lowest. The disease development is greatly influenced by the prevailing weather conditions. Nakuru district was characterized by high rainfall and low temperature at the period this study was carried out. In Meru at this time of the study the weather conditions were unfavourable for blight development explaining the low disease pressure.

The *P. infestans* isolates were found to vary in aggressiveness as indicated by their reaction on tubers and detached leaves. This variation can be explained by the differences in the genetic make up of the isolates. The variation in aggressiveness of *P. infestans* could result from oospore production that has been reported in mating and selfing tests in culture (Hohl, 1998; Mukalazi *et al.*, 2001, Kedera *et al.*, 2002). In selfing, an isolate can act as a male or female during heterothallic hybridization. Extraneous factors have been reported to induce oospore production in culture. Grooves and Ristaino (2000) reported high oospore numbers in cultures amended with fungicides. Cultures amended with Ridomil 2E and Ridomil Gold 2E caused particularly high numbers of oospores. In Kenya, Dithane M45 and Ridomil are the most widely used fungicides in potato. The use of fungicides could probably have caused the emergence of more aggressive *P. infestans* strains compounding the management of late blight.

Management of late blight has been addressed by the use of late blight tolerant varieties (Landeo, 1996). While these are

likely to contribute significantly to integrated control of this disease, it is important to note that the stability of their resistance is dependent on the aggressiveness of the *P. infestans* isolates. The Kenyan populations of *P. infestans* have evolved rapidly since the introduction of potato cultivars with more late blight tolerance genes. The US-1 genotype of *P. infestans* presently in Kenya is evolving to produce strains that are more aggressive with high insensitivity to metalaxyl creating new challenges in late blight control.

Pathogenicity tests and infection of tubers by different *P. infestans* isolates revealed significant differences in cultivar response. This observation is in agreement with reports by (Lapwood, 1965). Aggressive isolates are reported to have a lower latent period and a high sporulation index thus enhancing fitness for survival (Peters and Platt, 1999). Several isolates were virulent on varieties Tigoni and Asante implying that these two varieties are succumbing to late blight due to the emergence of aggressive biotypes. The varieties were released in the year 1997 based on the high level of foliar resistance to blight, high yields and superior processing qualities (Walingo *et al.*, 2002). Across cultivars, Tigoni although with high foliar resistance had the highest value of tuber rot. The variety is late maturing and therefore does not meet farmers early demand for food. The farmers being commercially oriented would like to capitalize on high prices before the glut period and therefore the variety is harvested immaturity (Walingo *et al.*, 2002). It is therefore prone to mechanical damage in which the pathogen can enter and initiate rotting during storage as well as in transportation to long distance markets. Most farmers use the forked jembe and the ox-drawn ploughs to uproot the mature tubers (Ng'ang'a, personal communication) resulting in mechanical injuries to the tubers that further facilitate the penetration of *P. infestans*. The emergence of these highly aggressive isolates may significantly increase tuber losses in storage.

The variety Kerr's Pink and Dutch Robyn exhibited high levels of susceptibility to all *P. infestans* isolates confirming reports by other workers (Lung'aho *et al.*, 1997). These varieties in contrast revealed high tuber resistance to late blight. Tuber resistance can be attributed to both physical and chemical means. Schoer (1980), while working with tuber resistance in different potato cultivars, reported that synthesis of a suberin wall around the inoculated portion of the tuber inhibits further proliferation of the mycelia. For biochemical reactions, phenolics, glykaloids and phytoalexins are produced in higher quantities in varieties with high tuber resistance. These varieties can therefore be stored for considerable periods even with the emergence of virulent strains of *P. infestans*. They are popular with processors for making into crisps as they have high dry matter content and can be stored for long periods (Walingo *et al.*, 1997; Ng'ang'a *et al.*, 2001). The varieties also tuberize early therefore could escape from build up of inoculum later in the growing season. In addition, being early maturing, the varieties are able to offer food to the farmers as well as capture high prices before the market is flooded. In times of low rainfall, farmers are able to obtain reasonable yields as the varieties are able to utilize limited quantities of water. The emergence of virulent strains also means that the farmers will increase the dosages of fungicides or reduce the spray intervals. Both of these are likely to have detrimental health and environment effects. Furthermore, the increased cost involved in potato production will also impact negatively on the gross margins. The population shifts to more aggressive pathotypes of *P. infestans* with increased insensitivity to metalaxyl has compounded late blight management strategies previously developed.

Between the two newly released varieties, Kenya Sifa and Kenya Mavuno, only one isolate (032) was virulent on Kenya Sifa. These cultivars were released based on high level of foliar resistance to late blight, good yields and superior processing qualities. The

variety Kenya Sifa also has high tuber resistance to blight. The lack of correlation between foliar and tuber resistance imply that cultivars with high foliar resistance may not necessarily have high resistance in the tubers. These findings were in agreement with those reported by various workers (Plat and Tai, 1998; Stewart *et al.*, 1994). The renewed efforts to breed for late blight resistance against emerging virulent strains have unfortunately focused on foliage resistance (Sikka, 2001; Lung'aho, 1997) and underestimated the role of tuber resistance (Platt and Thai, 1998).

Recommendations

The pathogen population shifts to more aggressive pathotypes of *P. infestans* has compounded late blight management strategies previously developed. The tuber is the marketable portion of the potato and emergence of more aggressive strains of *P. infestans* that in addition infect tubers which imply that losses will extend to ware and seed potato stores. It is of paramount importance that in search of cultivars with high resistance, both foliar and tuber responses towards *P. infestans* are considered.

The natural migration of the US-8 (A2) lineage is expected to reach the African region in the near future and strategies to keep out these aggressive strains should be put in place. Continuous studies of the population changes of *P. infestans* should be done to monitor the presence of A2 mating type. Authorities monitoring importation of plant materials should prohibit the importation of potato tubers from regions where the A2 mating type is predominant in order to safeguard the potato industry in Kenya.

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Seed yam marketing in Nigeria: Determinants and constraints

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Abstract. Seed yam marketing in Nigeria is gaining recognition not only as an income generating enterprise but also in replenishing the stock of planting materials among yam farmers. This study examines the seed yams marketing in Nigeria, its determinants and constraints. Data collected were analysed using descriptive techniques and ordinary least square regression framework to identify the determinants of the quantity of seed yam traded. Results showed that males and females are proportionately engaged in this business. About 55% of the marketing agents were males while 45% were females. Volume of seed yam traded is determined by literacy level, marketing experience and the manner of displaying seed yam in the market. Limited capital endowment, high cost of transportation and limited storage facilities constitute major constraints in seed yam marketing in Nigeria. Provision of cheap and easily accessible sources of credit, and improvements in market access and storage facilities will enhance marketing efficiency and provide incentive to marketing agents.

Introduction

Yam (*Dioscorea* sp.) is an important staple and income generating enterprise in Nigeria. An average yam producing household earned as much as 3200 naira/annum from seed yam (Ugwu, 1990). Seed yam in particular has recently attracted special attention not only as a cash crop but also in replenishing the stock of planting materials.

Nigeria is the largest producer of yam in the world producing an average of 26.9 million metric tonnes per annum (FAO, 2004). In 1997 alone, Nigeria accounted for 75% of world yam production (Manyong *et al.*, 2001). The annual growth rate for the same period was 6% for yield and 10% for the area planted. Although Nigeria is the largest producer of yam in the world, there is still need for increasing its production to satisfy domestic and export demand. Increased production of yam is believed to be constrained by high cost of seed yams. This is probably because a large quantity of edible yams, up to 30% (3-5 tonnes per hectare) of the previous year's harvest may be used to plant a new crop (Okoli and Akoroda, 1995). This makes seed yams account for over 40% of yam production cost (Ugwu 1990, Nweke *et al.*, 1991).

Standard seed yams, however, vary with ecological zones and farming systems (Asumugha and Eluagu, 1999).

According to NRCRI, Umudike, the weight of seed yams ranges from 250g to 1 kg (Ezeh, 1998). These seed yams are cut into 25-gramme sets called minisets to produce whole tubers (seed yams). The miniset technology of seed yam production is reported to be economically viable and profitable with an internal rate of return of 110% at the farm level in Nigeria, when compared with the traditional method of seed yam production (Asumugha and Obiechina, 2001).

The idea of minituber (less than 50g) instead of the miniseed yam to produce whole but small tubers has been conceived (Ikeorgu, 2001). This is in an attempt to

eliminate the problems of cut setts or minisetts (Alighewi *et al*,1995; Igwilo,1998). These problems include the non-uniform sprouting of cut setts as well as fungal attacks. To sustain future growth in yam production for domestic and export demand, the issue of seed yam production and distribution need to be properly addressed.

Seed yam marketing has assumed a business dimension as a result of the growth in production. The producers now operate in a highly competitive market. Available information on yam marketing in Nigeria is on ware yam (Eluagu *et al.*, 1990). This paper addresses seed yam marketing in Nigeria. The objectives of the paper are to assess the marketing system for seed yam in Nigeria with a view to (i) analyse the determinants of the volume of distribution; and (ii) find the major problems encountered in seed yam trade in Nigeria. The paper is based on data generated in Nigeria as part of the IFAD/WE CARD/IITA poverty Alleviation and Enhanced Food Availability studies in the country.

Methodology

Sampling Procedure. The study was conducted in four major yam producing and marketing states chosen at random in 2001. These states are Benue and Nasarawa in the Northern zone, and Delta and Enugu in the southern zone (producing and marketing States). Both seed yam production and marketing information were collected from these areas so that there would be a link between production and marketing. Two urban and two rural markets in each state were studied (10 traders per market). Forty marketing agents per state were interviewed making a total of 160 for the four states.

Data Collection. Primary data were collected from the seed yam marketing agents using pre-tested questionnaires. In addition to the data collected from the marketing agents, observation of marketing activities were made. Data collected from the traders include system of marketing, quantity of seed yams purchased

and sold, markets and market prices on monthly basis for the season, and marketing constraints, among other factors.

Data analysis. Econometric and statistical techniques were used in data analysis. Descriptive statistics such as frequency counts, bar chart and mean scores were also employed in the analysis. The least-square multiple regression procedure was used to test the effect of a number of structural and economic variables on the quantity or volume of seed yams traded by the marketing agents.

Results and discussion

Socio-economic profile of seed yam traders.

Table 1 and Figure. 1 show the characteristics of the seed yam marketing agents. The average age was about 46 years (minimum 25 years; maximum 85 years). These indicate that most of the seed yam traders were middle aged. This is the active farming and trading group. The mean number of years of schooling of the seed yam traders was about 6 years with a maximum of up to 26 years. Trading experience influences decision making in relation to risk aversion. The mean number of years in seed yam trade was about 15 years with a maximum of 55 years and a minimum of 2 years. About 55% of the marketing agents were males while 45% were females. This implies that both males and females are almost proportionately engaged in seed yam trade. The marketing agents were however mostly men in Moslem dominated areas but mostly women in non-Moslem areas.

The marketing system for seed yam is not elaborate (Fig. 2), especially with the marketing channels and environment. Seed yams are transported by village assemblers and sometimes the growers themselves to the rural and urban markets. These are then purchased by the retailers and consumers. The season for marketing seed yams is from November to July. Seed yams were sold in the open air and in covered sheds. Figure 3 shows that about 52 percent of seed yam traders displayed seed yam both in open air

Table 1: Descriptive statistics of seed yam traders.

Variable	Mean	Min	Max
Age of the trader	46.44	25	85
No. of years of schooling	6.38	0	26
No. of years in seed yam trade	14.43	2.0	55.0

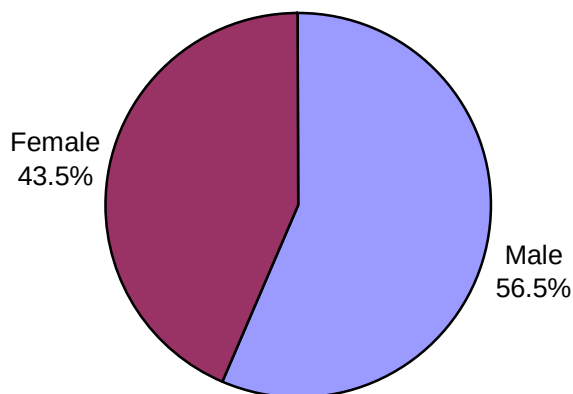


Figure 1: Percentage distribution of the Marketing Agents by Sex in Seed Yam Trade.

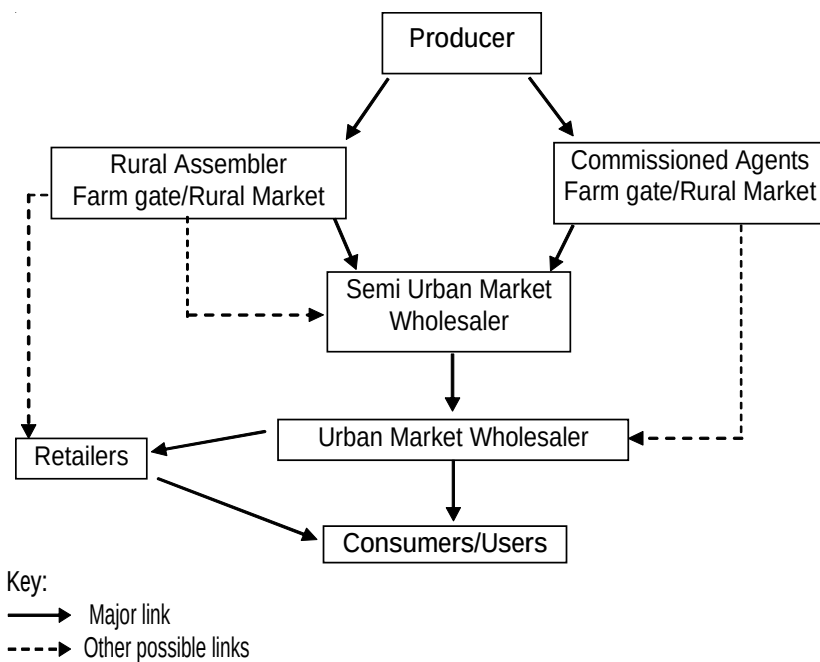


Figure 2: Marketing Channels for Seed yam in Nigeria.

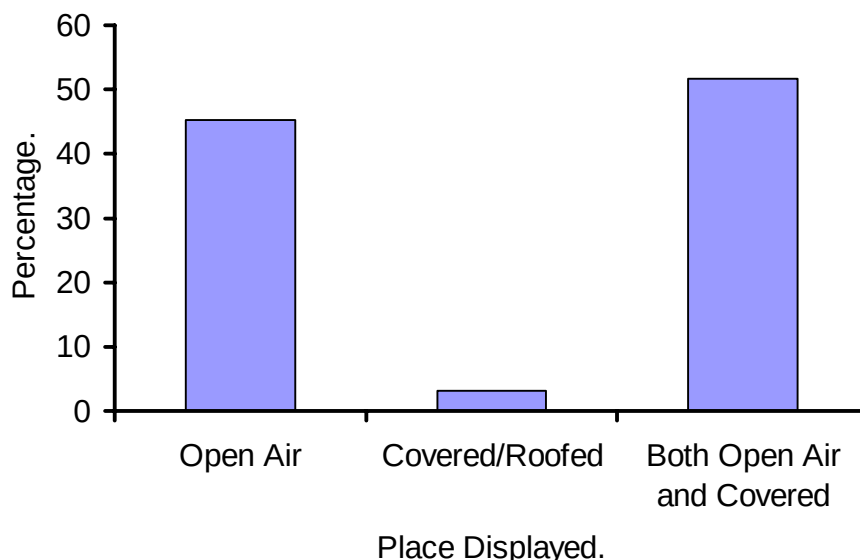


Figure 3: Percentage distribution of Seed Yam Traders according to how seed yams are displayed for sale in the Market.

and covered sheds, while 45 percent sold mainly in open air.

These traders limit their purchases to accessible rural markets. The traders have various reasons for sourcing seed yams from particular markets (Table 2). The reason for 23% of the respondents is that supply of seed yam is adequate and regular, for 20% of them the choice is governed by inadequate resources to explore other supply sources while for 19% of them the reason is the availability of high quality seed yams from such markets.

Monthly prices of seed yams during the sale season are given (Table 3). The sale period usually starts from November (at peak harvest) and lasts till June-July (period of late planting). The mean price of seed yams ranged from N10.36 to N25.24 per kilogram depending on the variety. Variety that yield large tubers surrounded with a number of seed size yams, are mostly expensive. Such varieties include *D. rundata* (white yam), *D. cayenensis* (yellow yam), and *D. bulbifera*. Price is high between March and June, the main planting period and low at harvest (October/November).

Factors influencing the quantity/volume of seed yams traded by the marketing Agents.

This section analyses the influence of specified economic variables on the volume of seed yams traded. Results of the least square multiple regression analysis is shown in Table 4. Quantity of seed yams traded per week was the dependent variable (Y).

The regression model explained 48% of the total variation. The estimated slope coefficient was significantly different from one at the 99 percent confidence level. Number of years of schooling had a positive and statistically significant effect on quantity of seed yam traded. Many school leavers and educated person are now involved in seed yam trade. The same result goes for number of years in seed yam trade ($P < 0.01$).

This result is expected. Experienced seed yam traders tend to have higher bargaining power, and they are better able to assess price and other variables that make for success in seed yam trade, than new entrants in the trade. Whether seed yams were sold in the open air or covered roof also had positive relationship with the volume of seed yam traded per week.

Table 2: Percentage distribution of marketing agents by their reason for sourcing seed yams from particular markets.

Reason	% of marketing agents
Supply is adequate and regular	22.53
Limited resources to explore other supply sources	20.37
Price of seed yams is relatively cheap	12.96
Nearness to market	12.96
Availability of high quality seed yams	18.83
Others	12.35
Total	100.0

Table 3: Monthly Prices of seed yams during sale season.

Month	Price (N/kg)			
	Mean	Std. Dev.	Min	Max
November	10.36	5.61	10.00	20.00
December	12.09	5.29	10.00	21.00
January	15.50	6.25	10.00	40.00
February	16.90	7.71	10.00	37.00
March	20.55	9.63	10.00	40.00
April	22.84	11.03	10.00	50.00
May	25.24	10.18	20.00	45.00
June	24.62	10.51	20.00	50.00
July	14.43	16.12	10.00	40.00

\$1 = N125 at time of study.

Table 4: Parameters estimates of the regression function on determinants of the volume of seed yam traded.

Explanatory Variable	Coefficient	t
Constant	.966	
Whether seed yam is displayed for sale in open air or in covered roof	.203	1.913*
Gender of Marketing Agent	-.159	-1.397
Age of Marketing Agent (years)	-.150	-1.107
Number of years of schooling	.269	2.685***
Number of years in seed yam trade	.339	2.632***
Whether big traders come regularly with lorries to buy seed yams	-.088	-.962

Note:

*** = significant at 1% level .

* = significant at 10% level,

$R^2 = 0.48$

$R^2 = 0.43$

Table 5: Percentage distribution on marketing agents by problems encountered in seed yam trade.

Problem	% of marketing agents
Limited capital endowment	27.61
Poor and limited storage facilities	12.33
High cost of transportation	12.87
High cost of seed yams	8.04
High level of competition	6.70
Incidence of tax at several levels	6.17
Others	26.28
Total	100.00

Constraints to seed yam marketing in Nigeria. The marketing agents were asked to list the problems that constrain trade in seed yams. Analysis of the factors believe to militate against efficient marketing of seed yams shows that limited capital endowment is a major problem (Table 5). Seed yam is expensive and this imposes a limit on the volume of seed yams that an agent can purchase. In fact, nearly 10% of the marketing agents recognized that high cost of seed yams also constitute a problem in seed yam trade. Poor and limited storage facilities and high cost of transportation were also identified as major constraints to efficient system of seed yam marketing. It was shown above that seed yams are perishable. Poor storage facilities will tend to increase the degree of perishability, which will directly affect the volume of seed yams traded. The volume traded will tend to be small unless the marketing agent is sure of good storage facilities.

High transportation cost increases marketing costs, making seed yams relatively more expensive, and thereby limiting the volume traded.

Conclusion and Policy Recommendations

Conclusion. This paper examined the system of marketing seed yams in Nigeria. The factors that promote or hinder trade in seed yam were analysed. Literacy level, trading experience and good storage facilities had positive

effects on the volume traded. Trade in seed yam was however constrained by lack of capital and poor market access, leading to high transportation cost, and poor storage facilities, among other factors.

Recommendations. Recommended policy measures were geared towards solving the identified constraints that impede efficient marketing of seed yams. The following issues need to be addressed.

(i) Provision of credit. Trade in seed yams is capital intensive and this tends to limit the volume of trade for many marketing agents who finance their business from personal savings. Incidentally, these people cannot easily obtain loans from formal credit institutions. On the other hand, interest rates at the informal sector tend to be too high. The Agricultural Credit Guarantee Scheme of the government and non-government organisations should evolve a credit delivery system that is easily accessible to the marketing agents.

(ii) Improvement in market access. The identified high transportation cost has to do with poor market access to many seed yam producing areas. Improving market access will improve market information. Government at various levels should devise ways and means of improving market access, as was once done in the days of the defunct Directorate of Food, Road and Rural

Infrastructure. This will facilitate food production and marketing.

(iii) Provision of good storage facilities.

There is need for improved storage facilities. Good storage facilities will make an impact on the volume traded and also enhance the quality of seed yams. The youths should also be encouraged to take up the seed yam business as gainful employment. Results of our analysis showed that seed yam marketers are mostly middle aged.

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Use of fluorescent *in-situ* hybridisation to investigate possible involvement of *Clostridium* spp. during softening and fermentation of cassava

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Abstract. This study was designed to investigate the possible role of *Clostridium* spp. in softening of cassava, using a novel molecular method “fluorescent in-situ hybridisation” (FISH). The technique can be applied directly to fermented cassava, and is used in parallel with conventional cultural isolation techniques. The use of FISH has been proposed to validate the results of cultural techniques and to determine the presence of components of the microflora that were not previously recovered. Peeled and unpeeled cassava pieces were incubated at 40°C, 37°C, 30°C and 25°C for 5 days. Compiled results of current and previous *in vitro* model cassava fermentations, demonstrated large variations in the extent of softening during fermentation. In the most recent study, however, the fermentation did lead to cassava softening. Although low numbers of presumptive *Clostridium* spp. were recovered using conventional cultural methodology, results obtained using the FISH technique failed to demonstrate the presence of this bacterium. It was concluded that, while there is some evidence for the presence of *Clostridium* spp. in cassava fermentations, further work on the methodology of FISH assays is required. Possible reasons for the failure of the technique to detect Clostridia are discussed.

Introduction

Cassava (*Manihot esculenta* Crantz) is an important starchy staple food consumed

mostly in the tropics. It is processed into various local products, thus providing a basic daily source of dietary energy. It is, however, associated with major nutritional limitations, being low in protein and micronutrients. It is often utilised in sub-Saharan Africa as the main diet of infants, and young children during the weaning and post weaning stage. Long term feeding, however, results in severe malnutrition due to a combination of protein and various micronutrient deficiencies (Mosha *et al.*, 2000). Cassava contains toxic cyanogenic glucoside compounds that can produce toxic levels of hydrogen cyanide in the range from 10 - 450 mg/kg of fresh root depending on variety (Tokuibiye *et al.*, 1996). Regular consumption of inadequately processed cassava can lead to chronic toxicity (Holzapfel, 2002). Various traditional processes exist for detoxification to improve cassava safety and digestibility before consumption. Fermentation reduces levels of cyanogens due to degradation by linamarinase (α -glucosidase) produced by lactic acid bacteria (Lei *et al.*, 1999). A reduction in cyanogen level results from soaking and retting and culinary activities, such as slicing, cutting and grating, that cause cell disruption (Gidanis *et al.*, 1993).

Cassava can be classified as sweet or bitter depending on the cyanogenic glucoside levels. Bitter cultivars are generally used as raw material for starch production, except in Africa, where they are consumed by humans. Variations in cyanogenic glucoside levels in cassava due to growing conditions, soil type,

moisture, temperature and age of the plant are superimposed on variations between cultivars. Cassava root has a major post-harvest constraint in being highly perishable, the poor keeping quality being caused by a number of factors, including physiological and microbiological deterioration (Borges *et al.*, 2002). Physiologic deterioration leads to vascular discoloration (streaking). Microbiological deterioration also occurs and is usually a consequence of tuber damage during harvesting and handling operations. Therefore, cassava must be processed into a storable form soon after harvest, if losses are to be minimised.

Traditional “wet” process for cassava. The submerged traditional cassava fermentation is spontaneous, uncontrolled and is associated with a complex indigenous microflora (Okafor *et al.*, 1984). It involves a lactic fermentation characterised by acidification, preceded by a retting stage, during which softening of the cassava may occur. It has been proposed that during submerged fermentation, pectin-degrading enzymes disrupt the cell membrane and alter its integrity. This process enhances removal of toxins through leaching into water during soaking (Westby *et al.*, 1997; Okafor *et al.*, 1984). Experiments with small-scale fermentations have shown a lack of reproducibility in the softening process. Observations were based on results of several repeat trials using both peeled and unpeeled cassava. These demonstrated a wide and unpredictable variability of cassava softening from batch to batch. At present, there is no rationale, which can fully explain such variations in the softening process; thus the underlying mechanism remains obscure and hypothetical. It is anticipated that full elucidation of the cassava softening mechanism will be a component key of strategies enabling optimisation of cassava fermentation and quality of end product. A number of studies have suggested that both bacterial enzymes and the endogenous enzymes of the cassava are implicated (Okafor

et al., 1984, Oyewole, 1992, Amoa-Awua, 1999, 1995; Holzapfel, 2002). Despite this, the origin of pectinolytic enzymes in cassava fermentations remains obscure. No known member of the dominant lactic acid bacteria produces these enzymes and it is unlikely that these bacteria play a role in softening. Amongst the Enterobacteriaceae, which can also reach significant numbers in the earlier stages of fermentation, *Erwinia* spp. are well known for production of pectinolytic enzymes and associated cell disruption. There is no evidence, however, for a role for *Erwinia*. It has further been postulated that *Clostridium* spp. may be responsible for softening, but this also has not been substantiated. There is, however, supportive circumstantial evidence. This includes a strong odour of butyric acid, a fermentation end-product of some clostridia, when softening occurs but not in its absence.

The genus *Clostridium*. The genus *Clostridium* comprises Gram-positive, anaerobic endospore forming, rods. Although all members of the genus are obligate anaerobes, the degree of aero tolerance varies widely. The bacterium is common in a number of environments, including soil, marine and fresh water, and in human and animal intestinal tracts. Carbohydrate fermentation is a common property of clostridia, but alternative energy-yielding metabolic pathways exist in the group, including amino acid fermentation. *Clostridium butyricum* and a number of other clostridia (“butyric acid clostridia”) are able to ferment soluble carbohydrates, starch or pectin with the formation of end products such as acetic and butyric acids, CO₂ and H₂. In many natural environments *Clostridium* is of importance in mineralisation of organic matter and is a major component of the microflora that develops during the “retting” process. Retting is a traditional process, involving the softening of plant materials immersed in water. Degradation of pectin and other materials that give the plant cells their integrity is an important part of the retting process.

Cultural vs non-cultural methods in the study of fermentations. Until relatively recently, investigations of the microorganisms involved in fermentations were dependent on cultural methods, usually based on colony counting techniques. A major, and well-recognised, problem with cultural techniques is that only a relatively small proportion of the bacteria present is recovered. This can be a result of stress, and entry of bacteria into a viable, non-recoverable (VNR) state has received considerable attention when studying the behaviour of foodborne pathogenic microorganisms. In many cases, however, failure to recover microorganisms is a consequence of limitations in the colony counting procedure. Colonies may fail to develop for a number of technical reasons, including unsuitable composition of media, incorrect incubation conditions, or competition from other microorganisms that are better able to develop colonies on the agar surface. In some cases, it is possible to enhance recovery by modifying the media used and apparently minor changes in incubation conditions can also result in major improvements. Despite this, in many environments, a significant proportion of the microorganisms present remains unrecoverable by conventional cultural techniques. Descriptions of processes mediated by microorganisms, including fermentations, have tended, therefore, to give undue weight to those components of the microflora that are able to grow most rapidly on the media used. The development of culture-independent molecular techniques that are capable of determining the composition of complex ecosystems has greatly expanded the knowledge of many ecosystems. In habitats as diverse as the human gut and sub-surface sediments, for example, it is now recognised that the great majority of species cannot be recovered by cultural means. In the case of food fermentations, the assumption is often made that population structure is simple and dominated by one, or a small number, of microorganisms. While this assumption may

be correct in the case of dairy or brewery fermentations where starter cultures are added to a heat-treated substrate, molecular methods have revealed much greater diversity in fermentations, including plant material, than previously thought to exist (Ampe *et al.* 2001). Although molecular methods offer a powerful means of determining diversity and population structure in fermentations, use until relatively recently has been limited. This results from unfamiliarity with the techniques and cost and availability of materials such as primers. Newer techniques, such as fluorescent in-situ hybridisation (FISH), however, are relatively simple and allow microorganisms present in virtually any ecosystem, including fermentations, to be detected and identified at various levels of discrimination up to genus. Other molecular techniques have been developed, including denaturing gradient gel electrophoresis. This technique is discriminatory to species level, but requires a significantly higher level of manipulations than FISH.

FISH is a molecular tool based on DNA sequencing that enables simultaneous direct visualisation and identification of individual microorganisms. The technique provides a powerful means of detecting and characterising microorganisms such as *Clostridium* spp. that can be difficult to isolate using conventional cultural techniques (Moter and Gobel, 2000; Rycroft *et al.* 2001). The underlying basis for FISH is that any isolated DNA sequence or gene can be mapped to a specific bacterial chromosome. This enables labelled cells, or chromosomes, to be identified according to the nucleic acids contained within them. Fluorescently labelled pieces of nucleic acid (probes) of approximately 20 nucleotides in length are used. The probes are incubated in the presence of cells under appropriate conditions of temperature and ionic strength to permit specific hybridisation of probe to target nucleic acid. Cell types that contain complementary RNA sequences become labelled by the binding of the fluorescent probe *in-situ*. Labelled cells are then

visualised by fluorescent microscopy or flow cytometry.

Although FISH is a relatively straightforward technique, there can be difficulties in its use. The technique, for example, is dependent on availability of suitable primers, and the concentration of genetic materials of the specimen. There are also potential technical problems. Detection by fluorescent microscopy, for example, is relatively insensitive. Further, examination of a large number of samples is tedious and can be error-prone. Flow cytometry is automated and capable of high throughput, but equipment is expensive and considerable effort can be required to establish a working protocol. Despite the problems, FISH and other molecular techniques are highly effective tools for determining the microorganisms present in a wide range of ecosystems. Molecular techniques do not, however, replace the need for cultural methods, since at some stage full studies of the microorganisms using pure cultures is required. The most effective picture of fermentation, or any ecosystem, is usually, therefore, obtained by a combination of conventional cultural and molecular methods. This approach is being adopted in the current project, where the use of FISH is being investigated to determine the presence of *Clostridia* and any differences between cassava fermentations that exhibit softening and those that do not.

Aim of study. To investigate the possible role of *Clostridium* spp. in softening of cassava, using a non-cultural technique, fluorescent in-situ hybridisation in conjunction with classic cultural methodology. It is meant to provide data to support existing circumstantial evidence that *Clostridium* spp. is present in significant quantities during the cassava fermentation.

Materials and Methods

Model cassava fermentations. Cassava tubers were purchased in local shops in North

London. These tubers were mostly of the sweet variety and were imported mainly from Ghana and Nigeria. Their age was not known. The tubers were all characterised by a waxy, shiny skin mainly devoid of soil. It was probable that the tubers had been pre-treated to retard the post harvest deterioration, and thus extend the shelf life. There was usually, however, indications of the onset of spoilage. Peeled and unpeeled cassava tubers were cut into cylindrical pieces of 6 cm diameter and 1 cm width. A total of 150 g of each type of cassava was added to 300 ml of distilled water in lidded jars. The jars were tightly closed and incubated in air at 40°C, 37°C, 30°C and 25°C respectively for 5 days. Samples were taken immediately after preparation and after 1, 3 and 5 days for examination by conventional cultural techniques and by FISH.

Conventional cultural microbiology. Three media were used for detection and enumeration of *Clostridium* spp. These were reinforced clostridial agar (RCA), Columbia blood agar base containing horse blood and supplemented with polymyxin B (CBP) or neomycin (CBN). In the earlier part of the work, anaerobic conditions were obtained by use of gas generators (Oxoid, UK) in anaerobic jars and media were not prerduced. Subsequently, media and diluent was prerduced and isolation plates incubated in an anaerobic workstation (Don Whitley Scientific, UK) at 37°C for 48 hours. Isolates were presumptively identified as clostridia on the basis of Gram-stain and cell morphology and on inability to grow during incubation in air.

Lactic acid bacteria (LAB) were enumerated on de Mann, Rogosa & Sharpe agar (MRS; Oxoid UK) incubated anaerobically at 37°C for 5 days. Isolates were presumptively identified and assigned to species on the basis of Gram-stain and cell morphology and a negative catalase reaction. pH value was determined electronically.

Application of fluorescent *in-situ* hybridisation

Step 1: Fixation. Fermented cassava samples (10 g/each) were removed from the ferment, homogenised and centrifuged. The supernatants were treated with denaturing agents (pH 7.2) and stored at 4°C overnight to fix bacterial cells. Fixation is required to maximise penetration and retention of the probe, to remove possible interfering compounds and to protect the RNA from degradation by endogenous ribonucleases. The fixed cells were then washed in buffer solutions of pH 7.0.

Step 2: Hybridisation. The fixed bacterial cells (135µl) were mixed with fluorescent probe (50 ng/µl⁻¹: 15µl) and incubated at 55°C overnight in aqueous salt solutions. A commercial genus specific 16 rRNA targeted oligonucleotide probes labelled with the fluorescent dye Cy3 was used to detect *Clostridium* spp. Cy3 is used as dye to enhance brightness. The hybridised cells were subjected to washes in buffer solutions of appropriate strength.

Step 3: Post hybridisation. 6-diamidino-2-phenylindole (DAPI) solution (500 ng/ µl⁻¹) was added to hybridised cells as blue fluorescent counterstain, and placed in a hybridisation oven for 30 minutes at 55°C. The unbound probe was removed by washing in buffer.

Step 5: Mounting and visualization. The hybridised cells were filtered (0.2 µm pore membrane) and the filters were placed on glass slides and SlowFade[®] (Molecular Probes Inc, The Netherlands) was added to each filter. Cells were visualised using a Nikon Eclipse E400 microscope (Nikon, UK) fitted with filters for the DAPI stain (excited at 359 nm and emitting at 461 nm) and the Cy3 dye (excited at 550 nm and emitting at 565 nm).

Results and Discussion

Following the analysis of the outcome of fermentations, three main observations were made concerning softening.

- Softening was always accompanied by a strong odour, characteristic of butyric acid. The precise patterns led us to propose that this odour is produced by clostridia and that there may be a causal relationship between these bacteria and softening. This observation may agree with previous reports
- The degree of softening was variable under the same fermentation conditions. This was independent of size of cassava pieces. Various sizes of cassava were investigated, and the outcome was that in some cases the entire pieces softened. In other batches, only the outer part of cassava pieces softened, while the inner part was still hard. Occasionally one batch would contain a mixture of fully and partially softened cassava pieces. This strongly disagreed with previous findings with suggestion of influence of size (Okafor *et al.*, 1984).
- In every fermentation medium, pH was low due to acidification by lactic acid bacteria. Therefore, the low pH value was not related to softening. There was no consistent relationship between softening and specific parameters including temperature and time of fermentation or final pH. Although there was some inconsistency in results obtained from comparisons of peeled and unpeeled cassava, it was observed that softening was more common when cassava was peeled. There have been other indications that the skin of cassava contains compounds that can alter the course of the fermentation. This phenomenon has not yet been investigated systematically.

After an initial lag of 3 to 4 hours, growth of lactic acid bacteria was rapid and high numbers ($\sim 10^8$ cfu/g) were present after 24 hours, increasing only slightly as the fermentation continued. Softening was independent of both acidification rate and final pH and, for this reason, it is considered that lactic acid bacterial are not responsible for cassava softening.

Presumptive *Clostridium* spp. were detected on Columbia blood agar, supplemented with polymyxin B, in numbers up to 5×10^5 cfu/g when an anaerobic workstation was used and full precautions were taken to protect cells from oxygen. Recovery using anaerobic jars was markedly lower. Recovery was also lower on Columbia blood agar supplemented with neomycin, while reinforced clostridial medium was ineffective due to overgrowth by facultative anaerobes. Higher numbers were isolated when softening was extensive and the characteristic odour was present. At present, insufficient results are available to imply a causal relationship. Levels of clostridia in the order of 5×10^5 cfu/g would not, however, be expected to be sufficient to cause softening. Clostridia can, however, be difficult to recover, partly due to variation in spore germination. The increase in recovery when using fully anaerobic conditions is considerable, suggesting that the dominant clostridia are poorly adapted to growth on artificial media. This possibility requires further investigation.

It is proposed to extend the incubation time from 48 to 96 hours to permit full adaptation to growth in artificial media. Initial results of the FISH technique failed to demonstrate the presence of *Clostridium* spp. This may suggest that the colony counts are accurate, since the limit of detection using fluorescent microscopy is $\sim 10^5$ cells. It is also possible that the primers used are not suitable, or that signal strength is weak, due to low cellular ribosome content, a common problem with environmental samples (Amann, 2000). This can be a particular problem with unusual species. There have also been unsubstantiated reports of food components

interfering with binding. FISH is also highly dependent on technique (Moter & Gobel, 2000; Amann, 2000), and it is possible that improved results can be obtained through relatively minor modifications to the methodology.

Implications

It has been reported that the final product of the traditional cassava fermentation process is subject to quality variability (Sanni, 1993). A full understanding of the mechanism of cassava softening during fermentation, particularly at industrial scale, would provide opportunities for optimising the process. This would consequently increase the yield, improve the quality of the end - product and ensure a better market for it.

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Pasta production: Another under-exploited way of increasing cassava utilization

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Abstract. One of the contributory factors to low cassava utilization, despite its promising potential, has been attributed to limited utilization options. Whereas one area has been cited as poor utilization in the fresh state in the form of *kibabu*, other potential options have not been exploited fully in Tanzania. This study was conducted to establish possible levels of blending wheat flour with cassava flour, soybean flour or cassava starch, singly or in combination, to produce acceptable pasta and assess its acceptability. Wheat flour was used at a level not lower than 50% in the formulations. Also in each of the formulations, soy and cassava flour or cassava starch were used at 5, 10, 15, 20, 25, 45, and 50%. Results showed that it was possible to produce pasta from simple household Italian pasta making machine with all formulations except those with 45% or more of soy flour. All formulations with less than 80% wheat flour easily broke into small pieces, the extent of which depended on their composition, even prior to cooking. To produce cassava-based pasta, it was easier to work with the flour than pure cassava starch. The samples with 50:45:5 wheat:cassava starch:soy became porridge-like after cooking. Sensory evaluation results showed that pure wheat pasta was significantly ($p < 0.05$) more accepted than the remaining formulations in terms of colour, smell, taste, texture and general acceptability. The sample with 20% cassava inclusion was

the next most preferred. Formulations with more than 20% cassava flour and 10% soy flour were the least accepted in all sensory attributes investigated. It was therefore concluded that, for production of acceptable pasta products, the proportion of wheat flour in the formulation should not be below 80%. Further research is required to establish other factors, which could enhance acceptability of cassava- and soy-based pasta.

Introduction

Pasta is widely recognized as dough made by combining durum wheat flour – commonly known as semolina with a liquid, usually water or milk. In recent days, pasta formulations including non-wheat ingredients like sweetpotato flour and tapioca starch have been reported (Limroongreungrat and Huang, 2002; Muhammad *et al.*, 1999). The dough is made into different shapes and sizes then dried and stored (Herbest, 1995; Dexter and Matsuo, 1980). When it is needed to prepare a certain dish, the pasta is simply boiled with salt and served with sauces, curry, etc. If kept dry, pasta products can be stored, without refrigeration, for several years without noticeable deterioration in either nutritional or organoleptic qualities. For this reason, among others, pasta products remain among the popular foods of modern-day societies (Vansteelandt and Delcour, 1998; Herbest, 1995).

Food insecurity is one characteristic of most developing countries like Tanzania. As a consequence of this insecurity, protein-energy malnutrition (PEM) is rampant in most of these countries. Most people in these countries do not utilize fully the available staple foods, like cassava. This anomaly has been partly attributed to the limited utilization options and limited processing and/or preservation options (Mansour, 2003). Cassava, a high energy root crop, has limited utilization options which include; boiling the fresh root, grilling the fresh root, deep-frying the fresh root, and preparing thick porridge (*ugali*) from cassava flour. Most of these utilization options do not fit well in the life style of modern-day societies. Likewise, soybean – a high-protein legume crop – finds limited food applications in most developing countries, except those in Asia. There is still lack of appropriate small-scale processing options to produce organoleptically acceptable soy-based products.

In this study, cassava and soybeans were chosen as ingredients to be incorporated in pasta products. Cassava is a root crop that is cheap and readily available in most areas in Tanzania. It is a high yielding crop and can grow in many areas of the country. Cassava does not require high rain fall, it needs little inputs and care, and is resistant to diseases. Cassava flour of acceptable organoleptic and nutritional quality is easily produced from dried cassava roots. Soybean grows well in tropical countries like Tanzania. Despite this fact, many people in Tanzania do not commonly utilize this crop in their diets. Soybeans contain an enormous amount of high quality protein, about 42 – 46% by weight, which is known to be superior to all proteins of plant origin. Inclusion of cassava and soybean in pasta formulations was thus anticipated to serve three purposes; (i) to increase the consumption of cassava and soybean by modern-day, urban-based societies, (ii) to increase the income of cassava and soybean producing farmers by increasing the demand of the two crops, and (iii) to reduce the PEM problem among pasta consumers by

developing nutritionally balanced pasta products. Therefore the main objective of this study was to investigate the feasibility of producing, at a household level, acceptable wheat-cassava-soy pasta products for food security and income generation.

Materials and Methods

Preparation of materials. Acquisition of raw materials. Three raw materials were needed to produce the composite flours used in this study; wheat flour, fresh cassava roots, and soybeans. Wheat flour and other minor ingredients, like table salt and vegetable cooking oil, were obtained from a local supermarket. Fresh cassava roots and soybeans were obtained from the municipal market.

Preparation of cassava flour. Fresh cassava roots, as obtained from the market, were processed into cassava flour and cassava starch. For cassava flour, the roots were washed to remove sand and other impurities, peeled and split longitudinally into two halves to remove the mid rib. The rib-free halves were cut into several medium-sized pieces that were washed to remove any unwanted materials. The clean cassava pieces were then soaked in distilled water for 12h. After soaking, the pieces were washed again to remove mucilage and chipped using a manually operated cassava chipper into thin chips. The chips obtained were sun dried and milled into flour. The steps involved in the preparation of cassava flour, cassava starch and soybean flour are summarized in Figure 1.

Preparation of cassava starch. Clean, medium-sized cassava pieces (obtained as explained above), were grated by help of an engine-powered grater to obtain a fine cassava mash. The mash was thoroughly mixed with a big volume of distilled water (about 10 times the volume of the mash). The resulting slurry was sifted through a muslin cloth to remove cassava chunks and fibres. The chunk-free

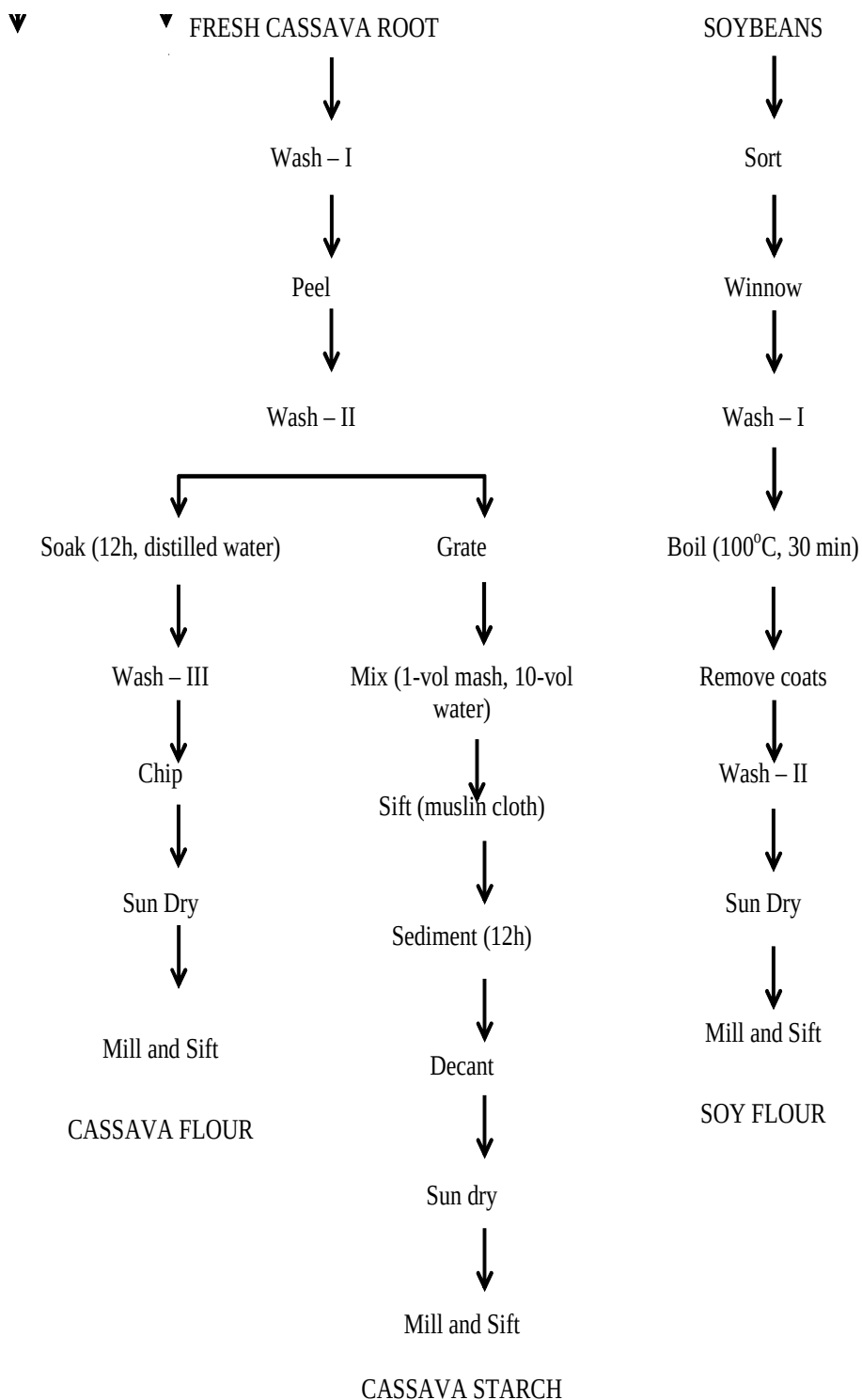


Figure 1: Steps for raw material preparation.

slurry was then rested for 12h, to allow starch particles to settle, before decanting the water and sun drying the starch. Finally the lumps of dry starch were milled to obtain cassava starch.

Preparation of soy flour. Dry soybeans, as obtained from the market, were sorted to remove unsound seeds, winnowed and washed. The beans were immersed in a pot of boiling water at about 100°C and allowed to boil for 30 minutes. The beans were hand-peeled to remove the seed coat, washed again and sun dried. When dry, the beans were milled to obtain full-fat soy flour.

Formulation of samples. Samples of composite flours were formulated by thoroughly hand-blending three ingredients in desired proportions. The three ingredients were; wheat flour, cassava (flour or starch, but not both) and soy flour. In all formulations,

wheat flour constituted at least 50% by weight. Each of the other ingredients accounted for 0, 5, 10, 15, 20, 25, 45 or 50% by weight. A total of 18 samples were formulated and coded as detailed in Table 1.

Production of Pasta. Production of pasta from the formulated composite flours followed a simple sequence shown in Figure 2.

Mixing. Dough of about 31% moisture (wet basis) was produced manually by working a mixture of composite flour (500g) and distilled water (about 225ml). The dough was hand-kneaded until it was smooth and homogeneous.

Extrusion. The dough, obtained after mixing, was cut into six approximately equal pieces. Each piece was flattened and run through the widest setting of a simple, family-sized, table-top Italian pasta-making machine (Marcato–

Table 1: Formulation of composite flour samples.

Sample code	Sample composition (% w/w)			
	Wheat flour	Soy flour	Cassava flour	Cassavastarch
A	100	0	0	0
Z	80	20	0	0
T	80	15	5	0
C	80	15	0	5
E	80	10	10	0
J	80	10	0	10
B	80	5	15	0
F	80	0	20	0
D	75	10	15	0
N	75	10	0	15
S	70	10	20	0
R	70	10	0	20
L	65	10	0	25
K	65	10	25	0
W	50	50	0	0
X	50	45	0	5
M	50	5	0	45
O	50	0	0	50

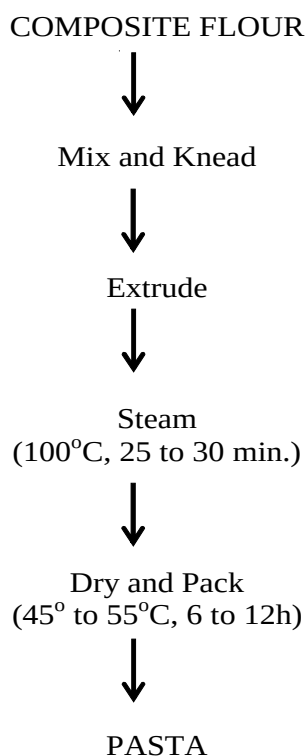


Figure 2: Steps involved in pasta production

ATLAS, Noodle Maker Machine, Italy). The dough piece was repeatedly run through the pasta-making machine, progressively reducing the nip between rollers, until a sheet of desired thickness was obtained. The dough sheet was rested for about 10 minutes before passing it through the cutting rollers of the pasta-making machine to obtain long run pasta strands (spaghetti).

Steaming. The freshly obtained pasta strands were steamed for 25 to 30 minutes. The pasta strands were carefully placed in a small cooking pot and covered with a clean piece of muslin cloth. The pasta-containing small pot was subsequently placed in a covered big pot containing boiling water on a hot plate. The level of boiling water in the big pot was kept low to avoid the water splashing into the pasta-containing small pot.

Drying and packaging. After steaming, the pasta strands were quickly separated from one another (as otherwise they tended to stick together), spread on the solar dryer trays and solar-dried for six to 12h. The dry pasta strands were packed in polyethylene bags ready for storage.

Sensory evaluation. Sensory evaluation was carried out to assess the acceptability of the formulated pasta products. Fourteen of the 18 samples were tested. The remaining four samples (M, W, O and X) were outright rejected as extreme cases and were not included in sensory evaluation. Five quality attributes were assessed; appearance, colour, texture, smell and general acceptability. A nine-point hedonic scale was used, where one stood for dislike extremely and nine stood for like extremely. The taste panel was constituted of a total of 25 untrained panelists.

Laboratory analysis. Samples of pasta products were analyzed for two important quality attributes of pasta; water absorption and cooking loss during cooking. Twenty grams of a sample were cooked for five minutes in 200ml of boiling distilled water. Water absorption, the difference in weight of the sample before cooking and after cooking and draining the cooking water, was expressed as a percent of the weight of uncooked sample. Similarly, cooking loss – the difference in weight of sample before cooking and after cooking, draining the cooking water and evaporating to dryness, was also expressed as a percent of the weight of uncooked sample.

Data analysis. Data analysis for results of sensory evaluation tests was done using a statistical package; Statistical Analysis System – SAS version 6.12 (SAS Institute Inc., Cary NC. USA). Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were employed for gathering inference on the data obtained in this study.

Results and Discussion

Pasta Production. It was possible to process most formulations into long run pasta products (spaghetti). However, for formulations X (WF:SF:CF:CS = 50:45:0:5) and W (50:50:0:0), it was difficult to get a sound dough. The dough obtained was very stiff and lacked elasticity. The low quality of the dough obtained was attributed to the high proportion of soy flour incorporated in the formulations (45% and 50%). It has long been established that the quality of pasta depends to the large extent on the amount and quality of gluten present in the dough (Delcour *et al.*, 2000). Although soy flour is rich in proteins, about 42% to 46% (Gueguen and Cerletti, 1994; Smith and Circle, 1972), this protein lacks viscoelasticity, characteristic of wheat gluten

(Gueguen and Cerletti, 1994). Sample O (50% WF and 50% CS), was too sticky. It was difficult, for this sample, to separate the pasta strands after steaming prior to drying. Also this sample was unique as it gave the lowest values for cooking loss and water absorption. This sample was therefore not included in sensory evaluation.

Cooking Loss. Cooking loss for the investigated samples ranged between 4.10% for sample O and 22.27% for sample R (70:10:0:20) (Table 2). The cooking loss for the wheat-alone sample (A) was 8.77%, which compared favourably with a value of 5.58% to 8.48% reported by Limroongreungrat and Huang (2001) for pasta products made out of modified sweetpotato flour supplemented with 15% to 30% defatted soy flour. Sample O

Table 2: Water absorption and cooking loss for composite flour-based pasta***.

Code	Sample				Sample weight (g)			Water absorption (%)	Cooking loss (%)
	Composition (%)***				Uncooked	Cooked and drained	Cooked drained, dried		
	WF	SF	CF	CS					
A	100	0	0	0	20.06	85.04	18.30	323.93	8.77
F	80	0	20	0	20.01	108.43	18.11	441.88	9.50
C	80	15	0	5	20.07	55.32	18.25	175.64	9.07
N	75	10	0	15	20.00	73.69	17.50	268.45	12.50
T	80	15	5	0	20.03	69.23	17.48	245.63	12.73
B	80	5	15	0	20.03	108.46	18.00	441.49	10.13
J	80	10	0	10	20.05	90.27	18.45	350.22	7.98
D	75	10	15	0	20.00	116.94	16.40	484.70	18.00
K	65	10	25	0	20.03	74.82	17.15	273.54	14.38
E	80	10	10	0	20.04	103.02	18.24	414.07	8.98
L	65	10	0	25	20.00	73.42	17.79	267.10	11.05
S	70	10	20	0	20.04	79.94	16.09	298.90	19.71
Z	80	20	0	0	20.00	61.63	16.29	208.15	18.55
R	70	10	0	20	20.03	96.02	15.57	379.38	22.27
M	50	5	0	45	20.07	141.65	17.17	605.78	14.45
W	50	50	0	0	20.07	84.50	17.51	321.03	12.76
O	50	0	0	50	20.00	60.81	19.18	204.05	4.10
X	50	45	0	5	20.07	86.77	16.47	332.34	17.94

* Entries are means of 2 replicates

** Samples were cooked in 200ml of boiling water for 5min.

*** WF = Wheat flour, SF = Soy flour, CF = Cassava flour, CS = Cassava starch

had the lowest cooking loss of 4.10%, implying very strong binding of its particles. This sample had 50% cassava starch, and as observed by Güler *et al.* (2002), the changes in starch particles shape during drying have the greatest influence on pasta's cooking properties including levels of starch loss. On the other hand, sample R exhibited the highest cooking loss of 22.27%, suggesting weak binding of its particles. The cooking loss did not follow any clear pattern with regard to sample composition.

Water absorption. Water absorption for the investigated samples, also known as cooking yield, ranged between 175.64% for sample C (80:15:0:5) and 605.78% for sample M (50:5:0:45). The wheat-alone sample had water absorption of 323.93%, which was reasonably close to the value of 335.68% to 346.75% reported by Limroongreungrat and Huang (2001) for the sweetpotato/soy flour-based pasta. Heat-induced modifications on the starch ultrastructure have been reported to influence the water uptake of pasta products and other low water content food systems (Lo and Ramsden, 2000). Increasing the proportion of cassava flour in the formulation seemed to increase the water absorption, while increasing the proportion of soy flour had the opposite effect. However, the effect of cassava flour and soy flour in the formulation, on water absorption, could not be confirmed conclusively.

Sensory evaluation. A taste panel of 25 untrained panelists was used to evaluate five sensory attributes (appearance, colour, texture, smell and general acceptability) of the investigated samples. The evaluation was based on a nine-point hedonic scale, with one standing for dislike extremely and nine standing for like extremely. A score of five was taken as a neutral point (neither like nor dislike), acting as a borderline between liking and disliking the product.

Appearance. A wheat-alone sample (A) was significantly superior ($P < 0.05$) in terms of

appearance than the rest. The only exception to this generalization was sample C (80:15:0:5) (Table 3). Ten of the 14 evaluated samples had acceptable appearance. The four samples with unacceptable appearance were D (75:10:15:0), L (65:10:0:25), S (70:10:20:0) and K (65:10:25:0) in that order of increasing unacceptability. The percentage of wheat flour in the formulation had a positive correlation with appearance ($r^2 = 0.703$). That is, increasing the proportion of wheat flour in the formulation improved the appearance of the product, and vice versa. For the non-wheat ingredients (soy flour, cassava flour and cassava starch), the correlation was poor, with r^2 values in the range 0.0013 to 0.3198. Nevertheless, there was a consistent trend of worsening appearance as the proportion of these non-wheat ingredients increased.

Colour. For this attribute, a wheat-alone sample was not significantly different ($P > 0.05$) from samples F (80:0:20:0), C (80:15:0:5), N (75:10:0:15) and J (80:10:0:10). The acceptability of pasta products, in terms of colour, increased as the proportion of wheat flour increased ($r^2 = 0.5261$) and decreased as the proportion of non-wheat ingredients increased. Three of the 14 evaluated samples had unacceptable colour; K (65:10:25:0), S (70:10:20:0) and E (80:10:10:0) in that order of increasing unacceptability.

Texture. The texture of a wheat-alone sample was in a class of its own, significantly better ($P < 0.05$) than that of the other samples. Like the other attributes, texture also improved with increasing proportion of wheat flour in the formulation ($r^2 = 0.6702$). The texture of four samples was not acceptable; L (65:10:0:25), E (80:10:10:0), S (70:10:20:0) and K (65:10:25:0).

Smell. The smell of a wheat-alone sample was superior to that of the other samples but not significantly different ($P > 0.05$) from that of samples F (80:0:20:0) and J (80:10:0:10). Again, the smell improved with increasing proportion of wheat flour in the formulation

Table 3: Scores based on a nine-point hedonic scale for five sensory attributes of composite flour based pasta (appearance, colour, texture, smell and general acceptability)*.**

Code	Sample				Sensory attribute				
	Composition (%)***				Appearance	Colour	Texture	Smell	General acceptability
	WF	SF	CF	CS					
A	100	0	0	0	7.833 ^a	7.167 ^a	7.500 ^a	6.967 ^a	7.533 ^a
F	80	0	20	0	6.484 ^{bc}	6.613 ^{ab}	6.548 ^b	6.129 ^{ab}	6.677 ^{bc}
C	80	15	0	5	6.936 ^{ab}	6.613 ^{ab}	6.355 ^b	5.968 ^b	6.323 ^{bcd}
N	75	10	0	15	6.032 ^{bcd}	6.323 ^{ab}	6.161 ^{bc}	5.484 ^{bc}	5.774 ^{bcd}
T	80	15	5	0	5.226 ^{de}	5.613 ^{bcd}	5.677 ^{bcd}	5.710 ^{bc}	5.516 ^{cde}
B	80	5	15	0	5.645 ^{cde}	5.774 ^{bcd}	5.742 ^{bcd}	5.613 ^{bc}	5.774 ^{bcd}
J	80	10	0	10	6.000 ^{bcd}	6.226 ^{abc}	6.000 ^{bcd}	6.129 ^{ab}	6.258 ^{bcd}
D	75	10	15	0	4.742 ^{ef}	5.645 ^{bcd}	5.365 ^{de}	5.516 ^{bc}	5.452 ^{cde}
K	65	10	25	0	3.290 ^g	4.839 ^d	3.355 ⁱ	4.807 ^c	3.807 ^f
E	80	10	10	0	5.290 ^{de}	4.807 ^d	4.452 ^e	5.097 ^{bc}	5.000 ^e
L	65	10	0	25	4.677 ^{ef}	5.194 ^{cd}	4.516 ^e	5.323 ^{bc}	5.355 ^e
S	70	10	20	0	4.097 ^g	4.807 ^d	4.194 ^{ef}	5.581 ^{bc}	4.807 ^e
Z	80	20	0	0	5.742 ^{cde}	5.742 ^{bcd}	5.645 ^{bcd}	5.258 ^{bc}	6.161 ^{bcd}
R	70	10	0	20	5.388 ^{de}	6.032 ^{bc}	5.161 ^{cde}	5.839 ^{bc}	6.516 ^{bc}

* Entries are average scores for 25 untrained panelists.

** Entries in the same column followed by different letters differ significantly ($P < 0.05$).

*** WF = Wheat flour, SF = Soy flour, CF = Cassava flour, and CS = Cassava starch.

($r^2 = 0.5647$). Not surprisingly, the smell worsened with increasing proportion of the non-wheat ingredients, particularly soy flour. Only one sample had objectionable smell; K (65:10:25:0).

General acceptability. The general acceptability of a wheat-alone sample was significantly superior ($P < 0.05$) over the other samples. As expected, the general acceptability improved with increasing proportion of wheat flour in the formulation ($r^2 = 0.5261$). Only two of the 14 evaluated samples were generally unacceptable; S (70:10:20:0) and K (65:10:25:0) with sample K being the most unacceptable.

Conclusions

This study revealed that it is feasible to produce acceptable pasta products by blending wheat flour with soy flour, cassava flour and cassava starch. Inclusion of these

non-wheat ingredients will undoubtedly increase the utilization of cassava and soybeans, particularly to the urban-based, modern-day societies. Also these non-wheat ingredients, particularly soy flour, will certainly improve the nutritional quality of the resulting pasta products. However, this should be done with care if the acceptability of the resulting pasta products is not to be compromised. The proportion of wheat flour in the formulations should be kept high (not less than 80% w/w) as this has the strongest influence on all the five tested sensory attributes, as well as other non-sensory quality attributes of pasta, like water absorption and cooking loss. The proportion of soy flour in the formulations should be kept low as this ingredient has adverse effect on all the five tested sensory attributes, particularly smell. Cassava starch is the most interesting ingredient. It has the minimum effect on all the tested quality attributes of pasta (both sensory and non-sensory

attributes) compared to the other non-wheat ingredients. However, the presence of cassava starch in the formulation makes the production of pasta a lot more cumbersome than the other ingredients.

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Nutritional potential of the under-utilized indigenous root tuber *Nymphaea petersiana* in Malawi

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Abstract. Demographic, health and micronutrient surveys in Malawi show that the nutritional status of the population is very poor, and has not improved during the last decade. Micronutrient malnutrition is particularly severe. For example, sub-clinical vitamin A deficiency was found in 60% of pre-school children, 38% of school children, 57% of women of childbearing age and 38% of men. Eighty percent (80%) of pre-school children, 27% of non-pregnant women, and 17% of men were anaemic. The national strategy to deal with this problem is multisectoral intervention involving many collaborating partners. One strategy being promoted is the utilization of readily available indigenous crops. One such indigenous crop is a wild water lily root tuber called “nyika” (*Nymphaea petersiana*), which grows abundantly in the wild in the extensive swamps of the lower Shire river in Chikwawa and Nsanje districts. Nyika tubers are commonly used as sources of food in times of famine and/or poor harvests. Whole cooked tubers are sold in markets as a snack food, or the tubers are peeled, cut into small pieces, dried and ground into flour. The flour is cooked into nsima, the national dish, which is eaten with different types of stews and vegetables. Nutritional analysis of the Nyika tuber revealed it to be a good source of quality protein (about 8%), limiting only in lysine. Although the fat content is low (1% crude fat), the predominant fatty acids in the tuber were essential fatty acids like oleic (47%), linoleic (37%) and linolenic (7%). More importantly was the high content of iron (100 mg/g of uncooked sun dried tuber). 100 mg

of uncooked sun dried tuber supplies approximately 88% of the recommended daily allowance (RDA) of iron in children and 59% of the RDA in women. This amount of iron is higher than the reported values for other common root tubers such as cassava (78 mg/g), potato (7 mg/g) and sweetpotatoes (20 mg/g).

Introduction

Traditional, neglected and under-utilised crops provide a wide range of options to address the complex interface between food insecurity and health problems. They provide resources and mechanisms specific to the conditions and needs of different households and communities in specific agroecological areas. In particular, they contribute to resilient and reliable food security systems. They can improve the diets of poor farmers, they can provide new income-generating options suitable for many households. They also entail an integral approach to food security as cultural values and local food habits are respected and enhanced.

Rural people are often custodians of a rich diversity of crops and crop varieties that are usually neglected and under-utilized. Some of these crops are sometimes despised as “traditional” or “indigenous” in comparison to the handful of economically valuable crops that are relevant in agricultural trade and urban food habits. These traditional, neglected and under-utilised crops are excluded in agricultural policies and programmes, to the

extent that their use and dignity have even declined among rural people themselves. Indigenous crops represent strategic crop genetic resources in household food security and nutrition, whilst providing many options for improving rural livelihoods and addressing evolving needs. They comprise crops and crop varieties that have strategic values and potential including advantageous adaptations to local agro-ecological constraints, such as drought, poor soils, and provision of superior nutritional sources. For example many neglected legume crops have high protein levels, and many leafy vegetables are excellent sources of micronutrients. Additionally, production of most of these crops is non-labour intensive.

During the last 2-3 years, drought, floods and insufficient agricultural inputs have resulted into famine in Malawi and other countries in the southern Africa Region. This food insecurity has been exacerbated by the HIV/AIDS pandemic. It is estimated that 16% of the population in the 15-49 years age group in Malawi has HIV. It is also important to recognise that people living with HIV/AIDS (PLWHA), even if they are asymptomatic, may have increased body metabolism, which increases their daily energy, protein and micronutrient requirements. An adequate and balanced diet for PLWHA is considered the only sustainable strategy to improve their health status and that of other people in general. More emphasis should be put on the use of indigenous and locally available foods with excellent amounts of micronutrients should be encouraged. Unfortunately many such foods have not been optimally exploited.

One such neglected and under-utilised root tuber is *Nymphaea petersiana*, locally known as Nyika which is an important water tuber in Southern Malawi. It grows abundantly in ponds and along the vast swamps of the Shire river. Nyika tubers are collected from waterways by small boats and canoes. These tubers are especially important as a food reserve during times of famine and poor harvests. Whole cooked tubers are

commonly sold in markets as a snack, or the tubers are peeled, cut into small pieces, dried and ground into a powder. The powder is cooked into a thick porridge (locally known as nsima), which is served with different types of stews and/or vegetables. Nyika tubers may be consumed up to four or more times a week.

Although *N.petersiana* tubers are widely consumed in southern Malawi, there is no available data about their nutrient composition or potential for toxicity. This study was therefore, undertaken to determine the tuber's content of selected nutrients and antinutrients and to assess how it might be best utilized in the Malawian diet.

Materials and Methods

Sampling and Processing of Nyika Tubers.

Tubers were collected from the Kademera and Chigumukire swamps of the Chikwawa and Nsanje districts of Southern Malawi. Care was taken to select only *N. petersiana* tubers for analysis. *N. petersiana* is the only species of waterlily in Malawi that have floating, sinuate-denated leaves (Flora Zambesiaca Managing Committee, 1960). Harvested tubers were put into cooler boxes with synthetic blue ice blocks and transported to a University of Malawi laboratory for analysis.

In the laboratory, the tubers were divided according to places of collection. Tubers were randomly assigned to one of two processing methods. In one method, the tubers were peeled, cut into small pieces, and sun-dried for 24-48 hours. The sun-dried tuber pieces were ground into powder using a cyclotec 1093 sample mill (Tecator, Hoganas, Sweden) and stored in plastic bottles at -4°C for further analysis. In the second processing method, the tubers were boiled in tap water for 45 minutes, peeled and freeze-dried. The freeze-dried tubers were ground into a powder and stored at -4°C.

Chemical analysis (Proximate composition).

The moisture content of boiled/freeze dried (BFD) and uncooked sun-dried (UCSD) tubers was determined by drying in a

Brabender Moisture Tester oven (Brabender Instruments Inc., South Hackensack, NJ) at 135°C for 2 hours according to AOAC approved method 7.007 (AOAC, 1984). The tuber %nitrogen was determined by the Kjeldahl method 2.057 (AOAC, 1984) and converted into crude protein by multiplying by a factor of 6.25. Crude fat was determined by the chloroform-methanol extraction method of Phillips *et al.* (1997). Dietary fiber content was determined using a total dietary fiber assay kit (Sigma catalog no. TDF-100A). Ash content was determined by decomposition in a muffle furnace at 450-620°C for 12 hours (AOAC, 1984). The percentage of total crude carbohydrate was obtained by the difference {100-(% crude protein + % crude fat + % moisture + % ash)} (Muller and Tobin, 1980). A standard reference material SRM 1544, a frozen diet composite, purchased from the National Institute of Standards & Technology (NIST), was run simultaneously with the tuber samples for method validation.

Mineral analysis. Tuber mineral analysis was carried out on wet-ashed tubers according to AOAC method 7.009 (b) (AOAC, 1984). Tubers were analyzed for calcium, zinc, phosphorus, and iron. Calcium and zinc contents were determined by atomic absorption spectrophotometry (ASS) according to AOAC method 7.100 (AOAC, 1984), using a Perkin-Elmer, Model 2100 atomic absorption spectrophotometer. Phosphorus was determined colorimetrically using AOAC method 7.126 (AOAC, 1984). Iron was determined by AAS using a Perkin-Elmer ICP Emission Spectrometer Plasma 400 (Norwalk, Connecticut). A standard reference material (SRM), 1515 Apple Leaves, purchased from NIST was run simultaneously with the samples for method validation.

Amino acid analysis. The UCSD and BFD tuber samples were also subjected to amino acid analysis using AOAC method 982.30E (a, b, c) and F(AOAC, 1990). The amino acids were separated and quantified using a Beckman 6600 automated amino acid analyser,

with a Beckman anion exchange column. Norleucine was used as an internal standard.

Fatty acid analysis. Fatty acids content of the tubers was also determined. The gravimetric method of Phillips *et al.* (1997) was used for extraction of total fat from the tuber samples. Extracted lipids were hydrolysed and esterified using 0.5N methanolic base (Supelco catalog no. 33080). The resulting fatty acid methyl esters (FAMES) were analysed by gas chromatography using a Shimadzu GC14A gas chromatograph with model AOC-14 Autoinjector and a Chromatopac C-R4AX processor (Shimadzu, Columbia, MD). FAMES were separated on a SP 2330 capillary column (Supelco, Bellefonte, PA) using temperature programming (from 60-100°C at 10°C/min, hold for 2 min at 100°C, then 10°C/min to 220°C). A set of short-chained C₄-C₁₂ and long-chained C₁₆-C₂₀ FAME standards were used to compare retention times of these standards to retention times of sample peaks eluted from the column as a means of tentatively identifying fatty acids in the tubers. FAMES were quantified using the internal standard technique, with heptadecanoic acid (17:0) as the internal standard.

Analysis of mono and disaccharides. The mono and disaccharide content of tuber samples was determined by high performance liquid chromatography (HPLC) following the method of Conrad and Palmer (1976) as modified by Johnson and Harris (1987).

Analysis of antinutritional factors. Tuber samples were also assayed for the possible presence of antinutritional factors. These factors were Trypsin and chymotrypsin inhibitors, cyanogenic glucosides, tannins, and phytates. The colorimetric procedure of Bradbury *et al.* (1991) was used to estimate the quantities of cyanogenic glucosides in the tuber samples. The UV-absorbance method of Kollipara and Hymowitz (1992) was used to determine trypsin and chymotrypsin inhibitor activity. The colorimetric procedure

of Wheeler and Ferrel (1971) was used to estimate the phytate content of the samples. Tannins were analysed using the method of Burns (1971).

Statistical analysis. Analysis of variance (ANOVA) was used to determine effects of processing method on nutrient amounts and occurrence of antinutrients in the Nyika samples. A randomised complete block design model was chosen for statistical design of this study. Significant processing effects were tested at $P \leq 0.05$. The analysis was done using the SAS statistical package (SAS Inc., Copyright, 1989-1995, Cary, NC).

Results and Discussion

Proximate composition. The proximate composition of UCSD and BFD tubers is presented on both a wet and dry-weight basis in Table 1. UCSD tubers were found, on a dry weight basis, to be significantly higher in crude protein and ash content than BFD tubers. The results suggest that some of the tuber's proteins and minerals may have leached into water during boiling. There were no significant differences in the dietary fiber content of UCSD and BFD tubers, implying that the majority of the dietary fiber is composed of water-insoluble fiber components such as cellulose, hemicelluloses and lignin.

A comparison of the proximate composition of Nyika tubers and some cereals eaten in Africa indicated that except for sorghum (10.7%), the protein content of the tubers (8.0 and 8.1%, on a wet-weight basis, for BFD and UCSD tubers, respectively) was comparable to that of the other cereals including that of the Malawian staple maize (7.9%). The protein content was slightly higher than the protein content of African millets (unspecified) (7.5%), and that of milled and polished rice (7.0%). Since the tuber contains approximately 8% protein, it can, under famine conditions, be substituted for the Malawian staple maize without compromising the protein content of the diet.

A comparison of the proximate composition of Nyika tubers and other tubers eaten in Africa (Table 1) indicates that the tuber has a higher protein content than cassava (1.2 and 1.3% protein for bitter and sweet varieties, respectively), potato (1.7%), sweetpotato (1.6%), yams (3.2 and 1.5%, wild and domesticated, respectively), and the Egyptian *N. lotus* (5.2%). Staple foods with protein contents below 3% (like those of most of the root tubers cited in Table 1) do not meet the protein requirements of humans even when ingested in amounts supplying more than food energy requirements. On the contrary, a diet with an 8-10% protein content meets the protein requirements of adults, provided enough is eaten to supply food

Table 1: Comparison of the proximate composition of Nyika with other African root tubers.

Crop	Protein (%)	Fat (%)	Total CHO (%)	Fiber (%)	Ash (%)
Nyika ^a (BFD)	8.0	1.0	88.4	13.0	1.9
Nyika ^a (UCSD)	8.1	0.8	78.1	12.0	2.2
Cassava ^b bitter (raw)	1.2	0.2	35.7	1.1	0.9
Cassava ^b sweet (dried)	1.3	0.05	86.6	1.8	2.9
Potato ^b (raw)	1.7	0.1	18.9	0.6	1.6
Sweet Potato ^b (raw)	1.6	0.2	28.5	1.0	0.9
Yam ^b , wild tuber	3.2	0.1	28.3	0.8	1.1
Yam ^b (African) tuber	1.5	0.1	26.5	0.9	0.9
<i>N. lotus</i> ^b , root (Eghyptian)	5.2	0.2	29.5	1.0	1.1

^aAll Nyika values are on a wet-weight basis.

^bSource: Food composition tables for use in Africa (Leung, 1968).

energy requirements (Cheftel *et al.*, 1985). This means that when eaten in sufficient quantities, *N. petersiana* tubers can meet the protein requirements of an adult.

The UCSD and BFD tubers had a higher fiber content than all the cereals and tubers listed in Table 1. High amounts of dietary fiber could, because of mineral binding to phytates and other dietary fiber components, reduce the bioavailability of zinc, iron and calcium (Zapsalis and Beck, 1985). Other dietary fiber components, specifically condensed tannins, are known to inhibit digestive enzymes, lowering the bioavailability of proteins and starches (Tamir and Alumot, 1969; Romero and Fyan, 1978). Dietary fiber has also been associated with a number of therapeutic effects. Increased consumption of dietary fiber increases excretion of bile acids in humans, which is associated with decreased risk of colon cancer (Haack *et al.*, 1998). A number of plant polyphenolic compounds have been shown to inhibit LDL oxidation (Vinson *et al.*, 1995; Kerry and Abbey, 1997). LDL oxidation is thought to be an early precipitating event in the development of cardiovascular disease in humans (Berliner *et al.*, 1995).

Amino acid composition. The nutritional quality of a food protein depends on the kinds and amounts of amino acids it contains, and

represents a measure of the efficiency with which the body can utilize the protein. A balanced or high quality protein contains essential amino acids in ratios that are sufficient to meet human needs. This can be determined by comparing the amino acid content of a protein to a FAO/WHO reference pattern (Cheftel *et al.*, 1985). The essential amino acid profiles of UCSD and BFD are shown in Table 2. The profiles indicate that the tuber is well balanced in essential amino acids except for lysine. Based on their lysine content, UCSD and BFD tubers had amino acid scores of 91 and 84, respectively. Knowledge of amino acid scores helps in estimating the complementary value of different proteins in a food mixture. In this case, the amino acid scores would help in deciding what cereals or legumes would complement the tuber if it had to be used as a weaning food, or what side dishes should be eaten with the tuber to complement the limiting amino acid lysine. Two possible choices available to Malawians are groundnuts (peanuts and bambarra nuts). Both are high in lysine and deficient in the sulfur amino acids (CFO, 1970) complementing Nyika proteins which are low in lysine but contain more than the FAO/WHO requirement of cysteine and methionine (Table 2).

Table 2: Comparison of essential amino acid content of *N.petersiana* (Nyika) tubers to a FAO reference pattern.

Amino acid	BFD tubers ^a	UCSD tubers ^a	FAO/WHO (1990) reference pattern ^b
Threonine	39 ± 0.5	39 ± 0.5	34
Cys. & Methionine	45 ± 0.5	46 ± 1.0	25
Valine	52 ± 1.7	52 ± 1.0	35
Leucine	86 ± 0.5	84 ± 1.0	66
Isoleucine	46 ± 2.4	45 ± 0.5	28
Phe. & Tyr.	101 ± 1.3	99 ± 0.5	63
Lysine	49 ± 1.5	53 ± 0.5	58
Tryptophan	26 ± 6.0	29 ± 1.0	11

^aReported values are in mg of amino acid/g of crude protein and are means and standard deviation of two determinations.

^bBased on prechool child data from FAO/WHO/UNU (1985).

Source: FAO/WHO/UNU (1985).

Minerals. Statistical analysis revealed that there were significant differences in the calcium, phosphorus, and iron content of UCSD and BFD tuber samples (Table 3). Approximately 20% of the phosphorus and 80% of the iron in the tubers presumably leached into the cooking water during boiling of BFD tubers. UCSD tubers appear to be an excellent source of iron. According to our calculations, a one hundred gram serving of the UCSD tubers would, on a wet-weight basis, supply approximately 88% of the USRDA for iron for children six months to 10 years of age and 59% of the USRDA for iron for women 11 to 50 years of age (NRC, 1989).

UCSD tubers had a higher iron content on a wet-weight basis (88.0 m/g) than reported values for cassava (78.0 m/g) and sweetpotato (20 m/g). A comparison of the mineral content of *N. petersiana* with other African root tubers (which are also eaten in Malawi) indicated that BFD tubers contain more calcium (1300 m/g) than cassava (480 m/g wild and 1210 m/g domesticated), potatoes (110 m/g), sweetpotatoes (330 m/g), and yams (520 m/g wild and 690 m/g domesticated). Phosphorus content (2200 µg/g and 2600 m/g for BFD and UCSD, respectively, on a wet-weight basis) was also higher than the reported values for the root tubers (Leung, 1968).

Other nutrients. Nyika tuber samples were found to contain a preponderance of polyunsaturated (approximately 30% linoleic and 6% linolenic acid) and monosaturated

(43% oleic acid) fatty acids (Table 4). Presence of high levels of unsaturated fatty acids is nutritionally desirable. However, unsaturated fatty acids are much more susceptible to oxidation than their saturated counterparts, therefore, exposure of tuber material to oxygen, light, and high temperatures should be minimized during processing and storage to prevent autoxidation of tuber lipids. Despite their high carbohydrate content, BFD and UCSD tubers were found to contain small amounts of the water-soluble sugars fructose (2.4 and 4.8mg/100g), glucose (3.0 and 6.0 mg/100g), and sucrose (0.05 and 0.35 mg/100g). There were significant differences in the content of glucose and fructose sugars between the two processing methods with the UCSD tubers having about twice as much of the two reducing sugars as BFD tubers. This might have been due, once again, to leaching losses of water-soluble mono and disaccharides from BFD tubers.

Antinutrients. The tannin content of *N. petersiana* was 1% and 1.5% in BFD and UCSD samples, respectively, which is lower than that found in sorghum (6.88%) from Uganda (Mukuru *et al.*, 1992). Boiling reduced the tannin content of the tubers which is in agreement with Price *et al.* (1980) who found that they could remove 33% of the tannins in sorghum grain by boiling the grain for 10 minutes. When fed to rats, the biological value (BV) of sorghum grain is significantly reduced by the presence of as little as 0.7% tannin (Muindi and Thomke,

Table 3: Mineral composition of boiled/freeze-dried (BFD) and uncooked/sun-dried (UCSD) *N. petersiana* (Nyika) tubers^a.

Tuber sample	Calcium (in µg of tuber)	Phosphorus (in µg of tuber)	Zinc (in µg of tuber)	Iron (in µg of tuber)
BFD tubers (wet-weight basis)	13000±49 ^a	2200±27 ^c	20±3 ^a	20±9 ^b
UCSD tubers (wet-weight basis)	928±48 ^c	2600±1 ^b	22±3 ^a	88±43 ^a
BFD tubers (dry-weight basis)	1309±48 ^a	2215±28 ^c	20±3 ^a	20±9 ^b
UCSD tubers (dry-weight basis)	1040±55 ^b	2914±1 ^a	25±3 ^a	99±48 ^a

^aReported values are means and standard deviations of eight determinations.

Table 4: Fatty acid composition of boiled/freeze dried (BFD) and uncooked/sun-dried (UCSD) *N. petersiana* (Nyika) tubers¹.

Tuber sample	%Palmitic acid (16:0)	%Stearic acid (18:0)	% Oleic acid (18:1)	%Linoleic acid (18:2)	%Linoleic acid (18:3)
BFD tubers (wet-weight basis)	21.0±0.6 ^a	2.0±0.3 ^a	42.0±1.0 ^a	30.0±1.2 ^a	6.0±0.5 ^a
UCSD tubers (wet-weight basis)	19.0±1.3 ^b	2.2±0.4 ^a	43.0±1.9 ^a	30.0±2.5 ^a	6.5±0.4 ^a

¹Reported values are means and standard deviations of eight determinations.

^{a,b}Means in the same column with different superscripts are significantly different at the P = 0.05 level.

1981), which suggests that the tannin content of the tubers is high enough to have significant negative consequences on nutrient bioavailability. Removing the tubers from their outer husks and then boiling them, may be a way of lowering the tannin content sufficiently to prevent such problems.

The phytate content of *N. petersiana* was 3.9µg/g and 5.4µg/g of tubers (BFD and UCSD, respectively, on a wet-weight basis). These values were very low compared to those found by Ferguson *et al.* (1988) for the Malawian staple white maize flour (in mg/100g) (211); cooked maize flour (55); unrefined maize flour (792); cassava (59); and sweetpotato (12). This indicates that the phytate content of *N. petersiana* tubers is so low to be of nutritional concern when compared with other foods commonly eaten in Malawi.

Nyika flour samples were also analysed for hydrogen cyanide, a compound released from cyanogenic compounds during heating. Boiled *N. petersiana* tubers have a slightly bitter taste (like that of some bitter cassava varieties) and this prompted us to analyze the tubers for cyanogenic glucosides common in bitter cassava. Hydrogen cyanide levels in both UCSD and BFD samples were below the limit of detection for the assay (LOD<16 nmoles/L), an indication that cyanogenic glucosides, if present at all in the tuber, are in negligible quantities and of little toxicological concern.

Trypsin and chymotrypsin inhibitor activity were significantly greater in UCSD than in BFD tuber samples. The trypsin

inhibitor (TI) activity in the tubers was reduced by a factor of about seven and the chymotrypsin inhibitor (CI) activity by a factor of five, by boiling (data not presented). Protease inhibitor activity in UCSD tuber samples was significantly greater than in uncooked soybeans that were purchased from a local health food store and assayed simultaneously for TI and CI activity. CI activity in BFD samples was slightly less (50 CIU/g of tuber) than CI activity in uncooked soybeans (52 CIU/g of seed) while TI activity (55 TIU/g of tuber) was less than half of the TI activity of uncooked soybeans (113 TIU/g of seed). These values indicate that although trypsin and chymotrypsin inhibitors were susceptible to moist heat; they were not fully inactivated even when the tubers were immersed in boiling water for 45 minutes.

Conclusions

Based on data presented here, Nyika tubers should be initially sun-dried rather than boiled to retain iron and maximize protein quality. Sun-dried tuber material should however, be consumed only after thorough cooking to ensure that trypsin and chymotrypsin inhibitors are inactivated. Future research should focus on the analysis of the nutrient and antinutrient content of Nyika based snacks and meals as they are prepared and eaten in Malawi. Research efforts should be expanded to include analysis of other essential nutrients and additional antinutrients.

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Determinants of the adoption of improved cassava varieties in Southern Ghana - logistic regression analysis

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Abstract. A benchmark adoption survey under the Root and Tuber Improvement Project of Ghana was conducted in 2001 to provide baseline indicators of adoption and impact for cassava. The sample size of the survey was 150 farmers selected at random from 18 agricultural districts under 5 of the regions of southern Ghana. The adoption rate for improved cassava varieties was 9%. The adoption intensity which is the area under improved cassava cultivation was 37% in the 2001 crop season. The mean size of fields planted to improved cassava by farmers was 3.6 hectares compared with 0.8 hectares by farmers planting local varieties. This means that farmers who plant improved cassava varieties may appear few but cultivate larger field sizes than their counterparts who plant local varieties. For farmers who never used improved cassava varieties, their reasons were related to availability of improved cassava planting material. Most of them did not know about the improved varieties or could not get them to plant. In a logistic regression analysis to determine the factors affecting the adoption of the improved varieties, land tenure, total field size farmed in 2001 and decisions with extension staff on cassava with farmers had positive and significant effect on the adoption of improved cassava varieties. Years of self-decision on farming and whether farmers had ever bought cassava cuttings were however, negatively related and significant. This suggests that farmers who have recently been in cassava cultivation are more likely to adopt improved

cassava varieties than their counterparts with longer experience. Gender and planting arrangement did not have a significant effect although they were positively related.

Introduction

Cassava is an important food security crop in Ghana. Yields from farmers fields are generally low, about 12 tons/ha compared with the achievable yield of 28 tons/ha. The Root and Tuber Improvement Project (RTIP) was set up to help increase production in farmers' fields by developing and extending improved technologies of root and tuber crops to Ghanaian farmers. Cassava was one of the target crops. In the course of developing and transferring technologies it was necessary to assess the adoption rates of the improved technologies and the factors influencing adoption. The results could serve as a feedback information to research, extension, policy makers and other stakeholders. The results could also be used as a measure of progress and the discovery of challenges for future research and extension in Ghana.

The purpose of this paper was to examine the adoption rate for improved cassava varieties and the key factors affecting adoption in Southern Ghana.

The Analytical Model. The use of discrete choice models such as LOGIT, PROBIT and TOBIT in explaining adoption are well documented (Shively, 1997; Tennassie and Sanders, 1996; Adesina and Badu-Forson

1995). These studies have variously used farmer and farmer characteristics and or farmer perceptions to explain the adoption process.

Understanding adoption behaviour goes beyond looking at single relations to multivariate relationships. Multiple regression may be used to analyse such relationships but the dependent variable must be continuous. Since many adoption studies deal with adoption as a “yes” or “no” dependent variable, LOGIT, PROBIT and TOBIT analyses are the appropriate tool.

Both LOGIT and PROBIT techniques use a series of characteristics of the farmer or the farm to predict the probability of adoption. LOGIT and PROBIT analyses give similar results. The difference is that while LOGIT assumes that the dependent variable follows a logistic distribution, PROBIT assumes a cumulative normal distribution.

The estimated probability of adoption in the LOGIT model is given by:

$$F(b'X) = 1 / 1 + e^{-b'x}$$

This is the cumulative probability distribution. The expression $b'X$ is defined as:

$$b'X = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_k X_k$$

Where:

$$b_0 = \text{constant}$$

$b_1, b_2, \dots, b_k$ = other estimated coefficient.

$X_1, X_2, \dots, X_k$ = values of independent variables.

With this expression, the probability of adoption of a new technology can be estimated.

In this study, the logistic regression model is used to determine the factors affecting the adoption of improved cassava varieties. The logistic regression gives the same results as LOGIT. The logistic regression can be rewritten in terms of the “odds” of an event occurring. The odds of an event occurring are the ratio

of the probability that it will occur to the probability that it will not. When the logistic model is written in terms of the log of the “odds”, it is called a LOGIT. The Logistic regression estimates directly the probability of an event occurring and is suited to models where the dependent variable is dichotomous.

The sample. Given the resources available and the fact that cassava is grown in all the southern regions of Ghana, a decision was taken to randomly select five out of the seven southern regions in Ghana. The regions chosen at random were the Ashanti, Brong Ahafo, Greater Accra, Volta and the Eastern Regions. The number of districts chosen per region was based on the number of districts in the region, the population (using the 1984 Population Census of Ghana) and the ecological zones. Based on these criteria, 5 districts in the Brong Ahafo, 4 in the Ashanti, 3 in the Eastern, 2 in the Volta and 4 in the Greater Accra Regions were selected among all the districts cultivating cassava in the region. A total of 18 districts were covered. The actual selection of the districts was made random but proportional to the area under cassava cultivation using the 1999 Production data from the Ministry of Food and Agriculture (MOFA). Thus a district with a bigger area under cassava cultivation had a higher chance of being picked. From these districts, 2 villages were further sampled randomly. Since it was not possible to obtain a list of all farmers cultivating cassava because almost all farmers planted cassava, houses in the villages were chosen at random and if a farmer fell into the sample, he or she was interviewed. In each village 5 houses were selected and a farmer interviewed in each of the houses. Thus, 5 farmers were chosen from each of the villages. Thirty villages were covered and the total sample size was 150. The districts sampled and their ecological zones are shown in Table 1.

In addition to frequencies, the logistic regression model was employed to determine the factors affecting the adoption of improved varieties.

Table 1: Sampled districts, Ghana.

Region	District	Ecological zone
Ashanti	Sekyerere East	Forest
	Ejisu-Juaben	Forest
	Amansie East	Forest
	Ashanti-Akim North	Forest
Brong Ahafo	Wenchi	Transition
	Tano	Forest
	Nkoranza	Transition
	Techiman	Transition
	Sunyani	Forest
Greater Accra	Ga	Coastal savannah
	Dangbe East	Coastal savannah
	Tema	Coastal savannah
	Dangbe West	Coastal savannah
Volta Region	Akatsi	Coastal savannah
	South Tongu	Coastal savannah
Eastern Region	New Juaben	Forest
	East Akim	Forest
	Fanteakwa	Forest

Results

Sample characteristics. The characteristics of the sample are summarized in Table 2. Male farmers formed about two-thirds of the sample and female farmers were one-third. Most of the farmers were natives of the towns and villages. Thirty two percent of the sample had no formal education. About half (49%) of the farmers had between 6 and 10 years of formal education. Age group between 20 years and over 60 years were involved in the cultivation of cassava. The age group of 30-39 years and 40-49 years formed over half of the farmers planting cassava.

Some descriptive statistics of the sample indicated that farmers began taking their own decisions between 1 and 60 years ago. The mean number of years of self-decision on farmers' cassava farm was 17.9 years suggesting that they have had a long experience in the cultivation of cassava. The size of main cassava field was between 0.04ha – 4ha and a mean of 0.8 ha.

A descriptive statistic of all land farmed to all crops in 2001 showed that the mean size of 1.32ha was farmed. Cassava occupied 61%

of the total area cropped to all crops by farmers in 2001. Most farmers (95%) cultivated cassava in a single field at a time and the rest had two or more fields.

Land ownership. An important ingredient to decision-making is land ownership. For cassava production, 70% of the farmers owned the land they cultivated, 14% rented, 13% sharecropped and 3% practiced communal or other land arrangements. These mean that majority of the farmers had rights to the land and got the benefits accruing from cassava farming.

Cropping systems. The majority of the farmers (83%) intercropped cassava with other crops and only 17% monocropped. Therefore, intercropping was the dominant practice. Farmers who intercropped and sharecropped planted significantly larger area of mean of 0.16ha compared with those monocropping and sharecropping of 0.04ha.

Adoption rate. Adoption rate may be defined as the proportion of the population practicing the new technology that, in this case, is the

use of improved varieties. The intensity of adoption, however, is the percentage of the area where the technology is used (Adesina and Zinnah, 1993). Both definitions are important in the analysis of adoption of improved technologies. The improved cassava varieties extended to farmers were Afisiafi, Tek bankye, Gblemo duade and Abasafitaa. The adoption rate for all the improved cassava varieties in 2001 (Table 3) was 9%. However, in terms of the area under cultivation referred to as the adoption intensity, the value for the improved varieties was 37%. This means that although few farmers adopted the improved cassava varieties, they planted larger area. Indeed, the mean size of farmers who planted improved cassava varieties was 3.6ha compared with 0.8ha of those planting local cassava.

Extension activities. Sixty-two percent of the farmers obtained their improved cassava

varieties from extension, 23% from research and 15% from other farmers. It is also interesting to note that farmers who planted improved cassava had significantly more discussions with extension agents than their counterparts who planted local varieties. The number of times farmers had discussions on cassava production techniques with extension agents between 1999 and 2001 was 8 compared with 2 for farmers planting local cassava.

Logistic model. The empirical Logistic Model was developed using farm and farmer specific characteristics. Since the variables are dichotomous, 1 is used if a farmer is likely to use improved cassava and 0, otherwise. The dependent variable is the adoption of improved cassava varieties (MCUSER). The other variables in the model are described in Table 4. The model takes the form

$$MCUSER = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8) + e$$

As shown in Table 5, land tenure, total area under all crops in 2001, and extension had positive coefficients and significant relationships. The significant relationship between land tenure and varietal adoption implies that owners are more likely to adopt improved varieties than tenants. This observation is consistent with the conclusions of Flinn *et al.* (1980). Similarly, the larger the total land cultivated to all crops by the farmer, and the more discussions on

Table 2: Characteristics of the sample.

Characteristic	Percent of farmers
Gender:	
Male	63
Female	37
Residence status	
Native	80
Settler	20
Formal education	
0 years	32
1-5 years	7
6-10 years	49
Over 10 years	12
Age (years)	
20-29	15
30-39	28
40-49	26
50-59	14
60 and above	17

Table 3: Adoption rates for improved cassava varieties, 2001.

Technology	Adoption rate (%)
Improved variety	
Afisiafi	3
Abasafitaa	1
Gblemo duade	5
Total (All improved)	9
Local	81

Table 4: Definition of the variables in the Logistic Regression equation

Dependent variable	
MCUSER	Improved cassava. 1 if improved cassava is adopted, and 0 otherwise.
Independent variables	
X	Land Tenure. 1 if land is owned and 0 if other land arrangements.
X	Total area under all crops in 2001. Measured as a continuous variable
X	Planting arrangement. 1 if cassava is planted in rows, 0 if planted at random.
X	Number of years farmer has taken his or her own decisions on his or her farm. It is measured as a continuous variable.
X	Size of largest cassava field. Continuous variable
X	Gender. 1 if female, 0 if male.
X	Ever bought cassava cuttings for planting. It is a binary variable: yes = 1 and no = 0
X	Number of extension discussions on cassava production. Continuous variable.
E	Error term

Source: Compiled by the authors.

Table 5: Indicator Variables for factors affecting adoption of improved cassava, Southern Ghana.

Variable	Coefficients	Standard Error	Wald	Degrees of freedom	Significance of level	R (Partial correlation)
X	2.3052	1.1954	3.7187	1	0.0538	0.1396
X	0.5609	0.1838	9.3160	1	0.0023	0.2882
X	0.6009	0.9189	0.4276	1	0.5132	0.0000
X	-0.0699	0.0353	3.9201	1	0.0477	-0.1477
X	0.4207	0.2353	3.1967	1	0.0738	0.1166
X	0.6314	0.9274	0.4636	1	0.4959	0.0000
X	-2.3177	1.0891	4.5285	1	0.0333	-0.1694
X	0.2155	0.0665	10.5155	1	0.0012	0.3110
Constant	15.3374	1.5709	11.5438	1	0.0007	

-2 Log Likelihood 53.937

Goodness of Fit 91.991

Cox & Snell – R² 0.206

Nagelkerke - R² 0.459

Percent of cases predicted correctly 91.89%.

improved cassava production with extension, the chances that farmers adopted improved cassava varieties. This is also consistent with other studies such as Padma and Flinn (1985). The number of years that the farmer has been taking his or her own decisions on his or her cassava farming activities and whether farmers had ever bought cassava cuttings to plant

were however, negatively related. This seems to suggest that farmers whose decision making was recent adopted improved cassava varieties than their counterparts with longer experience. Gender and planting arrangement did not show any significant effect although were positively related. Thus both female and male farmers may adopt the improved cassava

Table 6: Correlation matrix for variables in the Logistic Regression equation.

	Constant	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈
Constant	1.000								
X	-0.781	1.000							
X	-0.385	0.238	1.000						
X	-0.405	0.071	0.032	1.000					
X	0.119	-0.197	-0.570	-0.081	1.000				
X	0.052	-0.033	-0.563	-0.151	0.147	1.000			
X	-0.509	0.095	0.273	0.485	-0.161	-0.049	1.000		
X	0.140	-0.152	-0.499	-0.007	0.465	0.087	-0.105	1.000	
X	-0.179	0.167	0.453	-0.106	-0.474	-0.371	0.012	-0.510	1.000

varieties. Thus, the technology, improved cassava varieties seem not gender-biased. Planting arrangement had little effect. Thus whether farmers planted in rows or at random did not matter much when it comes to the use of improved cassava varieties.

The correlation matrix of the variables in the Logistic Regression used is presented in Table 6 and shows how the variables are correlated. The values of the correlation coefficients are generally low indicating that there are little relationships among the variables. This further suggests that the model is devoid of any serious multicollinearity problem and the variable selected for the analysis is appropriate.

Conclusion

Factors affecting the adoption of improved cassava varieties in Southern Ghana were examined through Logistic Regression model. The study reveals that adoption of cassava varieties is influenced positively by land tenure, size of land cultivated to all crops and number of discussions with extension officers on cassava production. However, adoption is negatively influenced by the length of farmer's decision-making on his or her own cassava farm and the fact that farmers buy cuttings for planting. These factors are important indicators to be considered in the transfer of cassava varieties to farmers in Southern Ghana.

The study also reveals that it is important to examine adoption not only in terms of number of farmers, but also in its intensity with regards to the percentage area under improved cassava cultivation.

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On-farm pre-treatment of yam tubers to extend shelf life

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Abstract. Yam is an important staple in Ghana and other West African countries such as Benin, Togo and Nigeria. In Ghana, it is mainly consumed in the urban centres and used for various food preparations. In recent times it has become an important non-traditional export crop second only to pineapples. Its major drawback is post-harvest storage/handling that affects availability, quality and affordability. Pre-treatment of yams prior to storage is considered as one way to overcome the problem. On-farm pre-treatment studies were carried out using three varieties of yam, Pona (Pu), Labareko (Ko) and Lobare (Lo). These were pretreated by dehydrating in the solar chamber dryer for 2 months. Physical observation and sensory evaluation of samples were carried out at various moisture reduction points. Moisture, ash, crude fibre, crude protein, carbohydrate and dry matter of the dehydrated products were determined relative to the fresh samples. Dehydrated samples were then stored for 5 months in yam storage barns traditionally used by farmers. Results of pre-treated samples showed enhanced taste at higher levels of dehydration with decreased mealiness with significant differences between the samples. Pu was the most acceptable variety followed by Ko and Lo. Samples had low crude fibre, ash and protein levels. Moisture content was in the range 64 - 71.35% with appreciable dry matter and carbohydrate levels. For the shelf life studies all varieties could store up to 7 months but Pu had relatively higher rots with Lo having the least. Lo had the highest sprouting (75%) while Ko and Pu had sprout levels of only 18.5 and 20%, respectively.

Introduction

Yam is a major staple used for various food preparations in Ghana and other West African countries such as Benin, Togo and Nigeria. It plays an important role in the socio-cultural lives of the people in the yam zone. In recent times it has become an important non-traditional export crop second only to pineapples and contributes substantially to the Agricultural Gross Domestic Product (AGDP) (Nweke, 1994). In spite of its potential, yam has not received the needed research attention especially in the area of post-production and marketing. Thus most farmers still use traditional storage systems that are associated with high storage losses. This forces farmers to sell their produce immediately after harvest at uneconomical prices. Among root and tuber crops, yam stores longest. However, the lack of effective storage system contributes in no small measure to the self in-sufficiency in production thus affecting availability, quality and affordability.

The high water content of yams at harvest significantly affects its storability as a tuber. It has been suggested that most agricultural produce can be preserved through pre-storage drying involving the quick reduction in moisture content by exposure to elevated air temperatures until the desired moisture content is attained (Fellows, 1992). Sun drying is the most widely used method for moisture reduction. However, pre-storage drying of yam tubers would require an improved system of drying for enhanced water removal due to tuber size.

The objective of this study, therefore, is to evaluate the effect of pre-storage treatment of selected yam varieties using a chamber dryer on shelf life extension.

Materials and Methods

Source of Yam tubers. Three varieties of white yam namely Pona (Pu), Labareko (Ko) and Lobare (Lo) were selected for this study based on preliminary survey results on yam consumption. Farm fresh tubers were obtained from 3 commercial farmers at Amponsakrom in the Wenchi district. They were transported to the study site at Kumasi.

Experimental design. A completely randomized design was used in the study and data obtained analysed by analysis of variance. The study was carried out in two parts; the first was to establish the appropriate pre-storage moisture level to use. This involved the use of sensory evaluation to evaluate the quality of selected yam varieties at 10%, 20% and 30% moisture reduction using the chamber dryer. In the second part of the study one moisture level was selected for the pre-treatment and shelf life study.

Sample preparation. For the first part of the study, 20 healthy tubers of each of the 3 varieties were selected, weighed and solar dried using the chamber dryer. Sixty healthy tubers of each of the three varieties were selected and treated as above. At about 20% moisture loss, samples were transferred from the chamber dryer to a barn and stored for 5 months.

Temperature and Relative Humidity determination. Temperature and relative humidity in the chamber dryer were measured at 9am, 12noon, 3pm and 5pm using a digital laboratory thermometer and a wet and dry bulb thermometer respectively. Corresponding values from the wet and dry bulb thermometer were read from a psychometric chart. During very hot days, the 2 vents at the back of the dryer were opened to prevent excessively high

temperatures (above 60°C) and vice-versa during cloudy and humid days.

Sensory evaluation. For the first part of the study, samples of each variety of yams were randomly selected at 10%, 20% and 30% moisture reduction points during the dehydration process. They were peeled, cut into slices of 3cm and boiled for 20 minutes for sensory evaluation. Using a 7-point hedonic scale and 12 panelists, samples were evaluated for taste, mealiness and texture and overall acceptability.

Analysis. For the second part of the study more analyses were carried out on the samples to assess the quality of the tubers prior to barn storage. Moisture, ash, crude fibre and proteins of tubers in the chamber dryer were determined using standard official methods (AOAC, 1990). Dry Matter content of the tubers were determined by drying 100g of the inner portion of 2-3cm cut pieces of fresh tubers to constant weight in an oven at 110°C and expressed as a percentage.

Barn storage. After 2 months of dehydration in the dryer, the tubers were all weighed to determine the extent of moisture reduction. They were then removed and sent to a farmer's field at Kwanwoma for storage under the traditional storage conditions. Tubers were monitored for any physical changes such rot or any form decay, sprouting and skin wrinkling.

Results and Discussion

Sensory results from the first part of the study showed that at 10% moisture reduction, there was no significant difference ($p < 0.05$) in the taste of Pona (Pu) and Labareko (Ko). However, differences existed between Pona (Pu) and Lobare (Lo) and, Ko and Lo. (Table 1). Mealiness and texture showed no significant difference, for all the 3 samples. Data showed that panelists preference for taste was Pu and for mealiness and texture, Ko. At 20% moisture reduction, significant

differences existed in the taste, mealiness and texture between Pu and Lo, and Ko and Lo but not Pu and Ko (Table 1). The panelists preference for the varieties was in the order Ko, Pu and Lo in decreasing order. At 30% moisture reduction there was no significant difference, in the taste of the 3 samples and also in the mealiness and texture between Pu and Ko. However, a significant difference existed between Pu and Lo, and Ko and Lo. Lo performed poorly with respect to texture and mealiness at 30% moisture loss. Preference was more for Pu and Ko. Thus based on the data obtained (Table 1), 20% moisture reduction was selected for the second part of the study due to the favourable response of the panelists.

The dryer temperature during the 2 months of dehydration was in the range 30 – 58°C with a relative humidity of 60 – 81%. The ambient temperature for the same period was

in the range 24 – 32°C with a relative humidity of 64 – 97%. However, during the 5 months of barn storage the ambient temperature was in the range 28.4 – 34.3°C.

Moisture content of the fresh tubers of the 3 varieties was in the range 64 - 71.35% and were consistent with data reported by Osagie (1992) which ranged between 65 - 81.0%. After dehydration, the moisture content of the tubers dropped to 44.57 - 45.07%; 45.18 - 45.86% and 46.94 - 47.44% for Pu, Ko and Lo, respectively (Table 2). The relatively high moisture content of edible fresh yam tubers is probably the greatest factor influencing storability.

Dry matter of the tubers was 30.27 - 30.79%, 34.01 - 35.95% and 36.05 - 37.01% for Lo, Ko and Pu respectively. For most agricultural products dry matter content has an inverse relationship with moisture content. Thus Lo with the highest moisture content had the least

Table 1: Mean values of sensory results on yam samples

Parameter	Varieties								
	10% moisture loss			20% moisture loss			30% moisture loss		
	Pu	Ko	Lo	Pu	Ko	Lo	Pu	Ko	Lo
Taste	4.1 ^a	4.3 ^a	4.9 ^a	2.3 ^a	2.4 ^a	3.0 ^b	1.6 ^a	1.7 ^a	1.9 ^a
Mealiness/Texture	2.0 ^b	1.9 ^b	2.3 ^b	3.2 ^b	3.1 ^b	4.0 ^c	3.5 ^b	3.6 ^b	4.8 ^c
Overall acceptability	3.3 ^c	3.2 ^c	4.1 ^d	2.8 ^c	2.7 ^c	3.3 ^d	2.6 ^c	2.3 ^c	3.1 ^d

Pu - Pona, Ko – Labareko Lo - LobareFor each parameter and moisture level, values with the same letter are not significantly different.

Table 2: Nutritional data on fresh and dehydrated yam samples

Varieties		Moisture (%)	CHO (%)	Ash (%)	Crude fibre (%)	Crude protein(%)	Drymatter (%)
Pu	Fresh	64.51-66.67	26.7-28.2	0.63-0.68	1.04—1.47	1.26-1.40	36.05-37.01
	Dehy	44.57-45.07	29.8-31.2	0.78-0.91	1.49-1.54	1.60-1.90	54.10-55.10
Ko	Fresh	66.25-67.99	24.8-26.5	0.70-0.78	1.51-1.70	1.54-1.95	34.01-35.95
	Dehy	45.18-45.86	28.5-30.2	1.01-1.12	1.72-1.76	1.98-2.00	52.40-53.10
Lo	Fresh	70.28-71.35	23.7-22.1	0.79-0.81	1.45-1.52	1.92-2.11	30.27-30.79
	Dehy	46.94-47.44	26.1-27.8	1.10-1.14	1.72-1.82	2.21-2.41	54.10-55.06

Pu - Pona; Ko - Labareko; Lo - Lobare, CHO – Carbohydrate Dehy. - Dehydrated.

dry matter content. Higher dry matter content indicates low moisture content and respectively higher nutrient content with anticipated reduced weight losses on prolonged storage of tubers. It also has implication for high yield when processed into products like flour. The trend was however different for the dehydrated samples.

There was an increase in ash content after dehydration for all the tubers with Lo having a slight but not significantly higher ash content (1.10 - 1.14%) compared to Ko (1.01 - 1.12%). Pu had the lowest ash level (0.78 - 0.91%) (Table 2). The relatively high ash content of the dehydrated samples is due to concentration effect as a result of the loss of water. The trend was the same for the fresh tubers ranging between 0.63 - 0.81% (Table 2). These values even though relatively low, reflect the mineral content in the food material. However, it falls within the range (0.60 - 1.70%) reported by Purseglove (1992). The ash content of the tubers depends on several factors such as soil mineral content, climatic conditions and harvest maturity.

Crude fibre content of the dehydrated samples was generally low (1.49 - 1.82%) with Lo having the highest range of 1.72 - 1.82%. Ko followed with 1.72 - 1.76% then Pu (1.49 - 1.54%). The values obtained for the dehydrated samples were higher than that of the fresh tubers (1.04 - 1.70%) as a result of the concentration effect. Osagie (1992) had reported crude fibre content of West African yams to be in the range 0.4% - 10.0%. The low fibre levels have some nutritional advantage, as higher fibre content may result into fibrous tubers on long storage. Generally tubers have low protein levels and this is reflected in the protein content of the yam tubers. The dehydrated tubers had protein levels in the range 1.60 to 2.41% with the fresh tubers having a range of 1.26 - 2.11%. for both fresh and dehydrated samples, Pona had the lowest level and Lobare, the highest. The observed levels are within the range reported by Osagie (1992) in his work on the nutritive value of West African yams.

Carbohydrate content was higher in the dehydrated tubers (26.1 - 31.2%) compared to fresh samples (22.1 - 28.2%) (Table 2). These values were higher than reported values for African yam (Ngambeki, 1981). The high total carbohydrate levels of the samples is an important attribute because yams in Ghana are consumed principally for the carbohydrate it provides.

Physical changes. During dehydration the percentage rot was in the range 5 - 12.5% with an average value of 8.33% (Table 3). Pona had the highest rot (12.5%) and Lobare, the lowest (5.0%). However, during storage in the barn the percentage rot was higher and was in the range of 5.26 - 21.52% (Table 4). Pona had the highest rot of 21.52% and Labareko the lowest (5.26%). Almost all these rots occurred within the first month of barn storage. This may be attributed to the sharp change in temperature between the chamber dryer (mean 44°C) and

Table 3: Observable defects during solar chamber dehydration (2 months).

Observable defects	Variety		
	Pu	Ko	Lo
Rots/Decay (%)	12.5 ^a	7.5 ^b	5.0 ^c
Skin Wrinkling (%)	5 ^d	2.5 ^e	10 ^f
Sprouts (%)	-	-	-

Pu - Pona, Ko - Labareko, Lo - Lobare. For each observable defect values with different letters are significantly different.

Table 4: Observable defects during barn storage (5 months).

Observable defects	Variety		
	Pu	Ko	Lo
Rots/Decay (%)	21.52 ^a	5.26 ^b	10.52 ^c
Skin Wrinkling (%)	-	-	-
Sprouts (%)	20.0 ^d	18.18 ^e	75.40 ^f

Pu - Pona, Ko - Labareko, Lo - Lobare. For each observable defect values with different letters are significantly different.

the barn (mean 31.08°C). Between the second and fifth months, no rot was observed.

Skin wrinkling was low during the dehydration process and ranged between 2.5 and 10% with Labareko having the lowest 2.5% and Lobare (10%) the highest (Table 3). However, during the 5 months barn storage there was no wrinkling or shriveling (Table 4). This may be due to a variety of factors including reduced moisture content, relatively lower storage temperature and good air circulation. Bushek and Lee (1978) reported that decreasing both moisture content and temperature prolong the preservation quality of products.

Sprouting was quite high in the Lobare samples (75.4%) with Pona and Labareko having 18.18% and 20.0% sprouting levels, respectively during the barn storage (Table 4). During dehydration, no sprouting was observed (Table 3). Generally, the initiation of sprouting in stored yams marks the end of dormancy period, which are controlled by external conditions. The vast difference in the degree of sprouting between Lobare and the other two varieties may be attributed to varietal differences and the relatively high degree of moisture reduction in the Lobare samples.

Conclusion

The study has shown that the application of pre-storage “accelerated” drying has the potential of extending the storage life of yam varieties. However, different varieties respond differently to this treatment. Further studies need to be carried out using large amounts of yam tubers and involving stakeholders to establish the true efficacy of the technology.

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Challenges, opportunities, and strategy for cassava sub sector development in Nigeria

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Abstract. Nigeria has substantial economic potential in its agricultural sector. However, despite the importance of agriculture in terms of employment creation, its potential for contributing to economic growth is far from being fully exploited. The sector's importance fluctuates with any rise and fall in oil revenue and has remained stagnant over the past ten years. The contribution of the manufacturing sector to the GDP declined over the same period. Inappropriate macroeconomic and sector policies perpetuated by the 15 years of military rule and mismanagement have had a negative impact, not only on agriculture but also on the entire economy. Presently, Nigeria grows more cassava than any other country in the world. Production has been driven primarily by the demand for food for its nearly 130 million inhabitants while very little is used for feed and industry. Estimates indicate that 52% of cassava output is wasted due to inefficiencies in production and processing, 43% is consumed as food while five percent is used as livestock feed. The question remains whether the country could reduce the amount wasted by diversifying utilisation to bring down levels of unemployment and rural poverty and enhance economic growth. Using data from primary and secondary sources, the paper assesses the challenges and opportunities in the development of the cassava sub-sector in Nigeria. At the moment, the country does not seem to have a comparative advantage in cassava exports due to inefficiencies in domestic production. There is a need to encourage product diversification to take advantage of the huge domestic and

regional markets. The paper recommends a market-led strategy with an emphasis on agro-industrial development and the mobilization of resources through partnerships to improve domestic efficiency and subsequently tap into regional markets in West and Central Africa.

Introduction

Over the past ten years, the Nigerian agricultural sector has remained stagnant while the contribution of the manufacturing sector to the GDP had declined over the same period. Inappropriate macro-economic and sector policies perpetuated by the mismanagement of resources have had a negative impact not only on agriculture, but also on the entire economy. Consequently, per capita incomes have declined from approximately \$1200 in the 1980s to about \$290 in 2002 (World Bank 2003).

Meanwhile, Nigeria is the largest producer of cassava in the world. Its production is currently put at about 33.8 million metric tons a year (FAO 2003). The Central Bank of Nigeria (CBN, 2002) estimates are put at 37.9 million t/ha in 2002. Total area harvested of the crop in 2001 was 3.1 million hectares with an average yield of about 11 tons per hectare. Cassava is the most widely cultivated crop in the country and the crop plays a vital role in the food security of the rural economy because of its capacity to yield under marginal soil conditions and its tolerance of drought.

Presently, cassava is primarily produced for food especially in the form of *gari*, *lafun*

and *fufu* with little or no use in the formal agribusiness sector as an industrial raw material. Data from the Collaborative Study of Cassava in Africa (COSCA) showed that 80% of Nigerians in the rural areas eat a cassava meal at least once weekly. Per capita consumption of cassava of 88 kg/person/year between 1961 and 1965, increased to 120 kg/person/year between 1994 and 1998 (Nweke *et al.* 2002). Population growth and urbanisation are the principal factors driving the demand for cassava as food in Nigeria. In 2002, the annual population growth rate in Nigeria was 2.1% per annum. Urban population (as % of total population) in Nigeria has also grown from an average of 26 % in 1980 to 45% in 2001 (World Bank, 2003).

Urbanisation in particular presents a unique opportunity for producers to produce cassava for larger but sophisticated markets. In the near future, urban growth and development in Nigeria will place a dynamic challenge to product and process development in cassava for food, feed and industrial raw material as the demand for affordable and convenient foods increases. Agro-processing and value addition forms the platform for employment and wealth creation in the cassava sub-sector. Emphasising the transformation of cassava into various forms for food, feed, and industrial raw material has the potential to help Nigeria improve its food security situation, diversify its manufacturing base, generate income and employment and achieve a favourable balance of trade. Nweke *et al.* (2002) maintain that Nigeria is the most advanced of the African countries poised to diversify the use of cassava as a primary industrial raw material and livestock feed. Two key factors put Nigeria in this comparative advantage: one is the rapid adoption of improved cassava varieties and the second is the development of small scale processing technologies including the cassava grater. Currently, there is a proactive support from the government of Nigeria towards the development of the cassava sub sector. But the country needs to surmount certain obstacles within its domestic market in order

to commercialise its cassava sub sector. The objective of this paper is to identify the gaps, challenges and opportunities in the development of the cassava sub sector and provide strategies for transforming the sector into an important economic activity for the country.

Methodology

This paper is based on information obtained from secondary sources in very current literature.

Production inputs. The commercialisation of the cassava sub sector will require an active and responsive private sector agricultural inputs market. The private sector inputs market in Nigeria is undeveloped and existing private sector inputs markets rarely service the cassava farmer. This is because it is assumed that cassava is a hardy crop produced by very poor farmers and its vegetative propagation nature discourages investment in improved seed.

In general, soils of the tropics are fragile and relatively low in nutrients. Low soil fertility is one of the greatest biotic obstacles to increasing cassava output and improving land productivity. For example, to obtain root yield of over 30 t/ha, 164 kg of Nitrogen, 31 kg of Phosphorus, 200 kg of Potassium, 80 kg of Calcium, 31 kg of Magnesium are mined from the soil at harvest (Asher, 1980). Over the past 30 years soil fertility has been declining as fallow periods have become shorter due to pressure on arable land resulting from increasing population. Applying soil amendments such as inorganic and organic fertilizers can ameliorate the problem of low soil fertility. Chemical fertilizers are by far the most important purchased variable input especially in terms of their yield impact on improved seeds and in terms of the volume and gross value of their consumption compared to other inputs.

Unfortunately, economic forces especially transportation costs, logistical defects, and delivery failures, keep fertilizer out of the

hands of many farmers (Idachaba, 2000). Fertiliser consumption in Nigeria is very low compared to other major cassava producing countries (Figure 1) because it is import dependent and domestic production has dropped. For instance in 2001, total fertilizer consumption in Nigeria was only 13% and 3% of the amount consumed in Thailand and Brazil respectively. Nweke *et al.* (1999) notes that the use of fertiliser in cassava production is much lower than in any of the other major food crops in Nigeria. Further development of the cassava sub sector in Nigeria will have to contend with the intractable problem of fertiliser supply distortions.

Pests and diseases. Various diseases and insect pests plague cassava and result in huge economic losses. These include the cassava mosaic disease (CMD), cassava bacterial blight (CBB), cassava mealybug, green spider mite (GSM), and the large grain borer, which attacks dry chips of cassava in storage. Others are termites, anthracnose, root rot, rodents, and stem girdlers. Cassava mealybug and GSM have been largely controlled through Africa-wide biological control efforts of IITA and its partners. White ants (termites) destroy planted setts before they sprout. Some areas appear to be very

prone to this problem. Various chemical control measures are recommended, but the need for safe use and high costs restricts their use among many small farmers who practice mixed cropping. Root yield losses due to cassava mosaic disease are as high as 70% on susceptible genotypes in Nigeria.

An emerging threat to cassava production in Nigeria is the incidence of the cassava mosaic disease (CMD). Recently, mixed infections of ACMV and EACMV, the two viruses that gave rise to the EACMV-Ug, have been reported in Cameroon, Nigeria, Ghana and Togo (Fondong, *et al.*, 1998; Fondong *et al.*, 2000; Offei *et al.*, 1999; Ogbe, *et al.*, 1999; Ogbe 2001; Ogbe *et al.*, 2003). The occurrence of ACMV, EACMV and their variants, in mixed infections in Nigeria, in addition to the possible spread of the virulent Ugandan variant EACMV-Ug to Nigeria pose a serious threat to the food security situation of the world's largest cassava producing nation.

Without pre-emptive measures to contain the virulent form of the cassava mosaic disease the estimated loss to the cassava industry in Nigeria would amount to ₦36 billion (US\$300 million) at 2001 production levels (Ezedinma, 2002). The collapse of the cassava industry would also lead to loss of jobs in the rural areas, loss of the processing

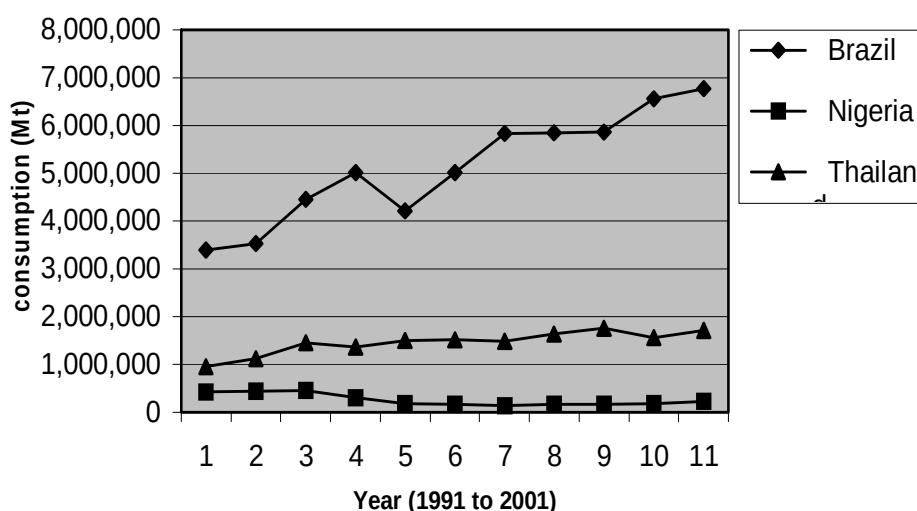


Figure 1: Total fertiliser consumption in major cassava producing countries.

and machine fabrication industry, and decimation of urban and rural food security. This may eventually lead to food scarcity, loss of confidence in government, and pressure on government to import food.

Agronomic challenges. Among the crops widely cultivated in Nigeria, research efforts have made the greatest impact on cassava. Production has increased substantially in the

country over the last twenty years principally owing to an increase in the area cultivated and improvements in production efficiency through the introduction of high yielding, disease and pest resistant cultivars (Figure 2). Cassava is produced mostly in the south and central zones of Nigeria (Figure 3). The collaborative study of cassava in Africa (COSCA) show that farmers in Nigeria obtain an average yield of 14.65t/ha without

Figure 2: Cassava production and area trend in Nigeria.

Figure 3: Comparison of domestic and world market prices for cassava chips, cassava starch and maize.

fertilizers. Fresh tuber yield (t/ha) range from 1.25t/ha to 67.2t/ha in Nigeria (Nweke *et al.*, 1999). While the average yield estimate by the FAO (2003) is 11t/ha, evidence from the COSCA in the early 90s show that farmers in Nigeria can attain equivalent yield levels as their counterparts in Thailand (16.4t/ha) and Brazil (13.7t/ha). This is because over the years, the international and national agricultural research centers have developed high yielding cassava varieties purposely for low input production. Manyong *et al.* (2000) have shown that by 1998 the use of such improved cassava varieties had increased the gross economic benefits per hectare by 142 US dollars in Nigeria.

However, the use of improved cassava varieties is not widespread in Nigeria (Nweke *et al.*, 1999; Ezedinma, 1989; Akoroda *et al.*, 1989). Shortage of planting materials is also compounded by farmers' inability to preserve planting materials. The lack of well-organized planting material multiplication and distribution system in Nigeria is also a major constraint. Hence breeding for high yield may not be the major challenge to cassava development but the multiplication, distribution and adoption of existing high yield varieties.

Challenges to agro-processing. In fresh form, cassava roots are bulky and perishable. Processing reduces the bulkiness and extends the shelf life and therefore reduces the transportation cost, as well as adding value to the product. The fact that cassava roots have to be processed before marketing may seem to make it less tradable than grains. But the vast majority of cassava roots are processed at the village level by a variety of small-scale methods into many different products that cater for local preferences. Small-scale processing machines namely graters, mills and press are available in the cassava producing zones of Nigeria (Nweke 1994; Ezedinma and Oti, 2001).

Available processing technologies especially graters and mills has reduced the use of manual labour in Nigeria by 50%

(Nweke *et al.*, 1999). The use of labour saving grating technology and improved cassava varieties has also improved income in rural areas. But the availability of the mechanised grater and improved cassava varieties has shifted the cassava labour bottleneck to harvesting, peeling and drying. The challenge therefore is to develop and transfer mechanised technologies that will improve cassava harvesting, peeling and drying operations in order to save labour and improve quality and standards. Consequently the likely enhancement in cassava production will occur only through "integrated and complementary" improvements in both cultivation methods and processing techniques.

Among other principal constraints to cassava processing are the absence of efficient dryers and pelletisers. Perhaps the greatest constraint to cassava processing is drying which takes up to 4 days to complete with solar energy with apparent loss in quality. Drying is a key process because in Nigeria the major cassava producing zones are also the relatively higher rainfall zones with longer rainfall months. Solar radiation is relatively low, justifying the need to use dryers extensively for cassava commercialisation.

Evidence (Omosaiye *et al.*, 2002) indicates that dryers (including flash dryers) using kerosene, diesel, charcoal and electricity are available, but their economic advantages have not been widely demonstrated in the country. Observations indicate that they are expensive because of inefficiencies in the use of energy. The development and promotion of efficient pelletising machines for making pellets either for poultry, ruminants, fish and for export is an engineering challenge as more Nigerians are becoming increasingly aware of production of pellets for animal feeds.

Market development and cassava commercialisation. Cassava has long been used as a famine reserve and food security crop produced mainly through smallholder subsistence farming systems. Low input use, rudimentary technology, large post-harvest

losses and limited processing characterize these farmers. Small-scale cassava producers (cultivating <2 ha) constitute about (95%), while those with more than 5 ha constitute about 5%. Production is not oriented towards commercialisation but instead farmers produce and process cassava as a subsistence crop. There is no scale advantage in subsistence cassava production using manual methods. Hence while it is true that Nigeria is the largest cassava producing country in the world, agro-industries may not be able to obtain adequate and reliable cassava supplies due to the dominance of subsistence production systems. Incentives are required to stimulate the commercialisation of the cassava sub sector. Such incentives include subsidy on fertiliser and agro chemicals and the introduction of tariffs on substitute imports such as cornstarch and ethanol to enable local industrial development in the sub-sector. The development of the cassava sub-sector also requires a complete re-orientation of farmers to think commercial. Commercialisation implies increase in the number of farmers who can produce cassava commercially with improved inputs and production practices at the farm level to meet the volume and quality requirements of emerging agro-industries in Nigeria. This is the major challenge in the industrialisation of cassava.

In Nigeria, production costs for cassava at the farm level are high relative to those in other countries. Average production cost/ton is as high as \$92.40 in the prevailing traditional production systems (Ezedinma, 2000). This contrasts with \$15.63/t in Indonesia, \$17.75/t in Thailand, \$22.51/t in India, and \$26.03/t in China (Howeler, 2000). It is the high cost of production that has placed Nigeria at a comparative disadvantage in the cassava export market (Figure 3). Reducing farm level production costs for cassava is therefore a major challenge in the development of the cassava sub-sector in Nigeria. An opportunity may lie in encouraging the cultivation of medium sized farms (10ha) using partly mechanised and partly manual labour. Since the soils, especially in the humid zones, are

fragile, the use of small (less than 20hp) tractors for land preparation, planting and harvesting may help mitigate rapid soil degradation. But in a semi mechanised production system labour for harvesting will still account for about 45% of the total cost of production (Olabashola, 2003) due to the absence of mechanised harvesters in Nigeria. The critical issue is that the subsequent introduction of yield-increasing technologies must be complemented with labour-saving mechanical technologies for cassava production and harvesting in order to drive down the price of cassava to consumers, feed millers, and industrial users.

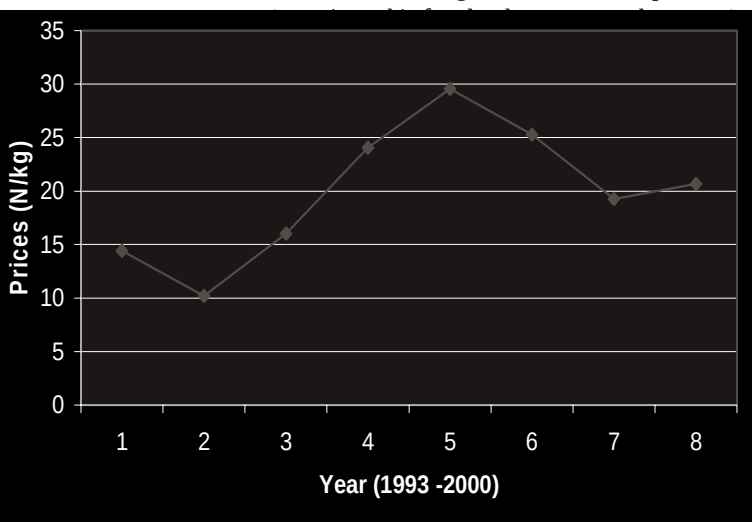
Another market related challenge is the fact that cassava production in Nigeria exhibits cyclical gluts due mainly to the inability of markets to absorb supplies. As a result when cassava is scarce the price goes up and farmers are encouraged to plant; production goes up and the price comes down prompting farmers to plant less until the price goes up again in a cycle of approximately two to three years (Figure 4). Such factors cause price instability over the years, which significantly increase the income risk to producers. The cyclical price movements for cassava justify the need to stabilize cassava prices through market expansion into other forms and uses.

Challenges to product and process development. In Nigeria, it is possible to broadly distinguish two markets, i.e. the traditional food-oriented market and the new emerging market for industrially processed cassava. The vast majority of the cassava grown in Nigeria is processed and sold through traditional market channels, which are fairly well known. Much less is known about the market structure for industrial cassava. Cassava *gari* has gained importance as a key food in urban households because it is convenient and easy to cook. Income elasticity estimates based on household food consumption and expenditure surveys (Kormawa, *et al.*, 2003; Nweke *et al.*, 1992) show that urban demand among households

Figure 4: Average annual market prices (N/kg) for gari in Nigeria, 1993 to 2000.

particularly in its main consumed form, as *gari* is positive. These results suggest that efforts to expand the domestic market for cassava should focus on the development of convenient foods including snacks from cassava. The challenge is to develop

from traditional foods to industrial uses, there is need to explore these opportunities to diversify cassava markets. The key to the successful commercialisation of the cassava sub sector lies in the development of a distribution system that links commercially



linked producers to urban consumers (process development) to enable a consistent supply of good quality products (product development) at a competitive price. Unfortunately, supply networks have yet to respond to the cassava transformation process (Ezedinma *et al.*, 2002) especially for supply of secondary cassava products. The primary source of raw material for agro-industries. Associated with these are problems of unreliable supply, uneven quality of products, low producer prices, and costly marketing structures, which affects its use for industrial transformation. Other than these constraints, cassava has great potential once its unique characteristics are capitalized on

processed into several secondary products of industrial market value. These products include chips, pellets, flour, ethanol, and starch, which are vital raw materials in the livestock, feed, alcohol/ethanol, textile, confectionery, wood, food and soft drinks industries. They are also tradable in the international market. With changing focus

as raw material for different end uses and product markets. Increasing the range and quality of consumer acceptable cassava-based products, its entry into the animal feed industry, and other industrial applications would raise the demand for cassava, provide the necessary incentive to improve production, expand trade and income

generating capacity of cassava producers and processors.

In a recent survey, Knipscheer *et al.* (2003) assessed the domestic opportunities for the industrial cassava market in Nigeria (Table 1). A potential market for cassava is in the livestock feed industry. However, the use of cassava for livestock feed in Nigeria is not competitive at the moment. According to the FAO (2003) only about 5% of the total cassava produced is used as feed indicating that the industry is under-developed. The current demand for cereals namely maize, a major carbohydrate source in the livestock industry is put at 1.2 million metric tons a year in Nigeria (Table 1). It is unlikely that cassava will completely replace maize as the basic energy source in livestock feed. This is because while cassava tubers are cheaper than maize the additional processing to chips and pellets for the livestock industry are prohibitive due to high processing costs. Cassava in its processed form as chips and pellets is not currently cheaper than the price of maize (www.rusep.org, 2003). This is because peeling and drying account for a greater proportion of the cost of processing due to the use of manual labour and solar energy.

The industry with the most potential for providing a rapid market for cassava is the ethanol industry. Until recently Nigeria imports all its ethanol since it stopped production in 2001 after cheap world market imports and a difficult domestic feed stock situation had undermined the viability of local production (www.ethanolmarketplace.com,

2003). Yield of alcohol per ton is much higher from cassava (150 litres/t of fresh root) than from sugar cane (48 litres/t) - a raw material source that had been used without much success in Nigeria (Bamikole and Bokanga, 1998). A distillery using cassava to produce alcohol can operate year round because cassava is available year round. The total market volume required in Nigeria is estimated at about 20,900t annually and 90% is used by the liquor industry alone. Substituting 80 million litres of imports with local cassava would require 500,000t of dried cassava roots (or 2 million tons of fresh roots) valued at (2003 prices) roughly 62 million dollars. Interest in investments in the Nigerian ethanol industry is growing but emphasis on small-scale cassava based production units using cassava, as raw material will generate equity and growth in the industry.

The use of cassava starch as an industrial raw material in Nigeria is low and the market structures are also under developed. In the early 1990s only about 700t of cassava starch was produced per annum because Nigerian cassava starch is considered to be of low quality by industries and none is exported (Nweke *et al.*, 2002). Maize starch rather than cassava was preferred especially by the textile and confectionery industries. The current demand based on imports of maize starch that can be replaced completely with cassava starch in 2002 is 67,100t (Table 1). The poor economic climate during the military era led to the near collapse of the textile industry in Nigeria and so reduced the potential market

Table 1: Potential domestic demand for industrial cassava in Nigeria, 2002.

Sector	Domestic Demand MT/year	Substitution (%)	Equivalent in fresh cassava roots (MT)
Animal feed	1.2 million (cereals)	20	1.0 million
Starch	67,100 (corn starch)	100	0.35 million
Flour	1.18 million (wheat)	20	1.0 million
Ethanol	20,900 (imports)	100	2.0 million
Total			4.5 million

Source: Knipscheer *et al.*, 2003.

for cassava starch. The positive steps taken by subsequent leadership to revamp the textile industry will provide an incentive to develop the starch industry.

Other potential markets are with respect to modified starch, which have several uses. The soft drinks industry imports all its syrup concentrate because cassava starch derivatives (hydrolysates e.g. glucose, sucrose, fructose, maltose, and syrup) are not currently developed in Nigeria. The estimated annual use of starch hydrolysates in the pharmaceutical industry is 1523t but 80% of the raw materials used by the pharmaceutical industry in Nigeria is imported because for now it is easier, less risky and much less complicated to import than to manufacture locally (RMRDC, 1997). Again in the 1990s, 58,000t of adhesives, a major derivative of starch (dextrin) were used in the wood, cable, paper and printing, packaging and footwear industries in Nigeria. Unfortunately, all these were imported either as adhesives or as dextrin. Developing the starch industry for use as adhesives for these industries would put 60,000t of cassava into use for this industry alone in Nigeria (Nweke *et al.*, 2002).

Opportunities in the regional market. At the moment, Nigeria is not a major cassava exporting country even though there is a large opportunity within the African region especially for cassava starch. Several countries in Africa import cassava starch totalling about 2.494 million tons in 2001 (Table 2). To gain access to these markets, the country needs to comply with international standards and negotiate trade terms with these African countries. Presently, Nigeria has no comparative advantage in the export of cassava chips and pellets to the EU because of stiff competition from Thailand (which dominates the export market at the moment), under developed inefficient marketing structures and the favourable domestic prices for maize (Ezedinma *et al.*, 2002; Nweke *et al.*, 2002).

The agribusiness environment and policy.

Investing in agribusiness enterprises in Nigeria is a big challenge arising from several factors within the domestic economy. For instance, available data from the Central Bank of Nigeria indicate that from an average of 75% in the 1970's the manufacturing capacity

Table 2: Cassava Starch imports in Africa.

Country	1999		2000		2001	
	Quantity (MT)	Value (1000\$)	Quantity (MT)	Value (1000\$)	Quantity (MT)	Value (1000\$)
Botswana	2	1	10	0	23	10
Burkina Faso	10		10		10	
Gabon	18	6	18	6	18	6
Kenya	132	38	160	53	160	53
Madagascar	4	3	0	0	75	29
Mauritania	204	54	295	72	400	77
Rwanda	52	49	52	49	0	0
Senegal	203	77	138	47	89	30
South Africa	1094	222	2777	388	2165	344
Swaziland	161	61	231	105	4	4
Zimbabwe	6	11	8	11	3	3
Total	1886	527	3690	731	2949	558

Source: FAOSTAT, 2003.

utilisation deteriorated to 50%, 40%, and 38% in 1983, 1987, and 1992, respectively. Throughout the 1990's capacity utilisation in the manufacturing sector fluctuated between 29% and 42% with an average of 35%. The low capacity utilisation in Nigeria's manufacturing sub-sector is attributed to a large variety of domestic factors. These factors include infrastructure deficiencies, high cost of inputs because of domestic currency depreciation, unstable and unpredictable government fiscal policy prescriptions, depleted production capacities of installed equipment because of poor maintenance and servicing cultures and inadequate support by government (Marchet *et al.*, 1999; Adeyemo and Bankole, 2003). On the issue of inadequate government support for production boosting incentives, Nweke (2003) recently notes that the absence of intellectual property rights protection to support private sector activities is a major challenge to cassava transformation in Nigeria.

Until recently, government had rarely intervened directly in the development of the cassava sub-sector. In 2002, the government of Nigeria committed itself to the development of cassava as a major export-earning commodity. In the coming year government intends to commit a lot more funds to the agricultural sector with specific allocations to cassava development. But there is still a need to set out new policy to guide the development of the sub sector. In the next section we discuss the strategy and policy requirements for the cassava sub sector in Nigeria.

Strategy for cassava sub sector development in Nigeria

Commodity chain approach. The best strategy in cassava development is to follow a market led approach within the cassava commodity chain. The commodity chain includes the inputs market, production at the farm level, agro-industrial processing, distribution and marketing, and consumption. Improvements in each chain (within the cassava commodity

chain) are urgently needed. The market led approach should target development where the private sector has made investments especially in the food, feed, and agro-industrial use. To gain efficiency in inputs and output markets and improve the supply chain, there is a need to encourage commercial farm and processing systems using a nucleus farm and cluster model (Knipscheer *et al.*, 2003). Developing commercial farming systems will not remove the subsistence production systems that have already gained efficiency in the traditional food sector. Commercial farm and processing also means the use of improved and purchased inputs and machinery.

Private-public sector strategy. The absence of a commercial approach to cassava production and marketing in Nigeria justifies a synchronized approach involving several partners in the development of the sector. A long-term cassava industrial and market development strategy that involves public-private partnerships is essential. The private sector will have to focus on investing in market development and procuring needed machinery, while the public sector provides the needed policy environment and physical infrastructure. The various actors in the partnership (i.e. farmers, processors, industrialists/investors) should remain in their own expertise. To strengthen the present weak link between industrial processors and producers of cassava products the sector will also require initial activities in capacity building especially producer and processor groups support and development, quality and standards in product development, transfer of production and processing technologies, and development of clusters to supply identified markets.

Focus on the domestic market and regional markets. To gain economies of scale in the industrialisation of the cassava sub-sector Nigeria has to focus on its domestic market. A comparison between the prices of Nigerian and Thailand cassava products clearly

indicates that – in the short run — Nigerian industrial cassava products cannot compete on the world market. However, Nigeria has a large domestic market. The domestic demand for animal feed, starch, crude alcohol and confectionary products are all increasing. By following a policy of import substitution, the Nigerian government can further stimulate the demand for homegrown cassava, while at the same time save foreign exchange. The development of the domestic market will help to improve industry, national and international standards, quality and global phytosanitary requirements leading to a gradual approach to export oriented production. In the short-run efforts to penetrate the world market to gain foreign exchange should focus on identifying niche or dedicated markets. Such markets could be explored within the African sub-regions and Europe.

Conclusion

In conclusion, we recommend new and additional roles for research and development institutions and for government and public sector institutions.

Research and Development. For sustainability, the cassava commercialisation effort must be supported by adequate research and development activities. Research and development institutions should focus on two critical issues that need to be addressed simultaneously. One is that the cost of cassava production and processing needs to be reduced to become more efficient. The second is that improved varieties need to be multiplied and distributed adequately.

Research and support activities should include the introduction of labor saving devices and appropriate processing technologies (planters, harvesters, dryers, peelers, pelletizers, etc.) and the development of high yielding and disease-free planting materials, plant health and resource-use management strategies, and postharvest technologies.

Machinery for cassava planting, dryers, peelers and pelletizers has been developed elsewhere. Initially, there would be need to import these, copy and mass-produce them and at the same time build domestic capacity to produce, maintain and repair them. Import incentives on the side of government would be required to achieve this.

Research and development agencies should play a market support role by targeting efforts in areas where the private sector is prepared to make significant investments. They should also support market linkages and supply chain organization. Supply chain organization includes the following: farmer organization and training, support and development of processor groups, build capacity in quality and standards in product development and in the transfer of production and processing technologies, and develop clusters to supply identified input and output markets.

Government and public sector institutions.

Develop a comprehensive policy for the use of cassava as a raw material in the food, feed, and agro industry on a commodity basis (e.g. starch, dextrin, ethanol, etc) to guide cassava development in Nigeria. In addition government should stabilise the investment climate with consistent policy incentives and security. Public and private sector research on product development and vertical/horizontal integration of industries should be supported with adequate intellectual property rights on the part of government. Government and its agencies should also support technology transfer and import substitution and strive to improve infrastructure especially electricity supply, railway transport, and water supply. At the moment great strides have been made in the area of information and communication technology.

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Farmers' participatory perspectives on sweetpotato cultivars in Makueni district of Kenya

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Abstract. Sweetpotatoes are a major source of subsistence and cash income to farmers in semi-arid regions areas of Kenya. KARI-Katumani in collaboration with the International Potato Centre (CIP) has been selecting and breeding sweetpotato clones for resistance to major biotic and abiotic stresses. Sixteen promising sweetpotato cultivars were planted at Kampi ya Mawe, Makueni district during the 2001/02 cropping season. The crop was harvested in March 2002 and farmers evaluated the cultivars based on taste and appearance. The best cultivars selected by farmers was Kanziga 2-1, Mogamba, Bikiramarua, 192100/103, Salyboro and Kanziga 1-1. The farmers' most important selection criteria were taste, appearance and yield in that order. Taste and appearance should be considered when breeders are developing new cultivars

Introduction

Sweetpotatoes are a major source of subsistence and cash income to farmers in semi-arid regions areas of Kenya. According to Onwueme (1978) sweetpotatoes has high potential for livestock feed and industrial use. In Kenya, sweetpotatoes are produced by small-scale farmers using traditional farming methods and marginal soils produce most of the sweetpotatoes. The yields of sweetpotato vary with cultivar, disease resistance, location and production practices (Onwueme, 1978). In Kenya, constraints to sweetpotato production include the sweetpotato weevil, viruses and lack of adequate disease and pest free planting materials, poor cultural practices,

lack of appropriate storage and processing technologies and poor market infrastructure (Luswetli *et al.*, 1997; Githunguri *et al.*, 2003).

In Kenya, sweetpotato covers about 75,000 hectares, or about 1.9% of Kenya's total arable land (Qaim, 1999). Its production has risen significantly during the last four decades, multiplying by a factor of 5. However, most of this is due to increases in the area cultivated and not production per unit area. The crop seems to be increasing importance as a result of pressure on arable land and declining farm sizes. In addition, the crop is adapted to marginal climatic and edaphic conditions. It also yields significantly higher amounts of calories per unit area under low-input production conditions. Sweetpotato production conditions differ by agro-ecological zone due to distinct agro-climatic and socio-economic factors. About 75% of its total production is concentrated in the humid and semi-humid lake Victoria basin in the Western region (Qaim, 1999). Although some of the producing areas in the Central and Coast Provinces have humid conditions, the majority of them are semi-arid. Table 1 shows the area and production estimates for each sweetpotato-growing region by 1998.

KARI-Katumani in collaboration with the International Potato Centre (CIP) has been selecting and breeding sweetpotato clones that are resistant/or tolerant to major biotic and abiotic stresses. KARI-Katumani has recognized the importance of involving farmers in their selection and breeding research programmes as suggested by Bellon (2001) and Fliert and Braun (1999). Research at KARI has identified a number of

sweetpotato varieties adapted to diverse agro-ecological zones, that are high yielding, early bulking, drought resistant/tolerant and resistant to major biotic and abiotic stresses. The objective of this study was therefore to evaluate the performance of 16 promising sweetpotato cultivars in Kampi ya Mawe, a semi-arid area in Makueni district of Kenya.

Materials and methods

The study was carried out with farmers. Sixteen promising sweetpotato cultivars were planted at Kampi ya Mawe, Makueni district during the 2001/02 cropping season. The sweetpotato cultivars were planted in November 2001 at the onset of the short rains. The cultivars were planted in 4-row plots at a spacing of 75x50 cm and replicated three times. Each row had 7 plants. Tanzania, a popular cultivar was included as a check. The crop was subjected to normal cultural practices, and kept weed-free for the first 6 weeks after planting.

The sweetpotato crop was harvested in March 2002 and subjected to a rigorous evaluation by farmers. The evaluations were based on taste and appearance. A trained panel of 16 farmers was used for the evaluations, which were conducted under the guidance of both the research and extension staff following the participatory method

suggested by Bellon (2001). At least half of the farmers were women. The data was computed as percentage of panel respondents.

Results and discussion

Characteristic of some of the sweetpotato germplasm held at KARI- Katumani in eastern Province of Kenya. Table 2 shows some characteristics of some of the sweetpotato germplasm held at KARI-Katumani. Farmers' evaluation of the sweetpotato cultivars in Kampi ya mawe, Makueni district Tables 3 and 4 shows the results of the farmers' evaluation of the sweetpotato cultivars. Cultivars Bikiramaria, Zapallo, Kanziga 2-1, Tororo, Kemb 10, Salyboro, 192100/103, Cemsa and Tanzania were the best top ten performers. Cultivar KSP20, the local check performed the poorest.

Based on appearance Mogamba (100%), 192100/103 (100%), Zapallo (100%), Kanziga 2-1 (88%), Salyboro (63%) were rated best. On the other hand, the six sweetpotato cultivars on the basis of taste are Kanziga 2-1, Bikiramaria, Mogamba, Kanziga 1-1, Salyboro and 192100/103. The farmers overall acceptability of the varieties was in order of preference Kanziga 2-1, Mogamba, Bikiramaria, 192100/103, Salyboro and Kanziga 1-1. Farmers emphasized that even though

Table 1: Sweetpotato Production by Area and tonnage (1996 -1998).

Province	Area (ha)	Production (t)	Production Share (%)
Nyanza	35,950	362,373	49.9
Western	17,953	180,971	24.9
Total	53,903	543,344	74.8
Rift Valley	3,675	32,485	4.5
Central	3,558	31,449	4.3
Eastern	12,414	109,744	15.1
Coastal	1,117	9,871	1.3
Total	20,764	183,549	25.2
Grand total	74,667	726,893	100.0

Source: (Quaim, 1999).

Table 2: Tuberous roots yield and dry matter content and foliage yield of different sweetpotato cultivars grown in Makueni (Kampi ya Mawe) District, Kenya, during the 2001/2002 cropping season.

Cultivar	Fresh roots yield (t/ha)	Dry roots yield (t/ha)	Root dry matter content (%)	Foliage yield (t/ha)
Bikramaria	14.5	3.8	26.5	21.4
Zapallo	11.0	2.6	23.5	13.3
Kanziga 2-1	10.8	3.6	33.2	13.6
Tororo	9.9	3.1	31.7	13.7
Kemb 10	8.2	2.8	34.0	13.0
Salyboro	8.1	2.8	34.1	13.0
192100/103	7.9	2.6	32.7	12.2
Cemsa	7.2	1.9	26.5	10.4
Tanzania	6.5	2.0	31.1	10.4
Mogamba	5.9	2.1	35.6	9.9
320/06	5.5	1.8	32.2	11.9
Kanziga 1-1	5.4	1.8	33.3	7.6
Tainon	4.9	1.5	30.3	5.5
316/02	4.0	1.4	35.2	10.0
91/316	3.9	0.8	21.2	5.4
320/07	3.8	1.7	44.8	6.7
Jayallo	3.5	1.2	35.3	5.3
Naveto	2.2	0.7	31.0	11.1
Kemb 36	2.2	0.8	36.5	16.3
KSP 20	1.4	0.4	30.0	4.4
Mean	6.3	2.0	31.9	10.8

Table 3: The farmers perception (in %) on the appearance of different sweetpotato cultivars grown in Makueni (Kampi ya Mawe) District, Kenya, during the 2001/2002 cropping season.

Cultivar	Appearance (%)			
	Good	Acceptable	Not acceptable	
	Undecided			
316/02	44	56	0	0
320/06	63	31	6	0
Naveto	56	38	6	0
Bikramaria	38	62	0	0
Cemsa	56	25	19	0
192100/103	100	0	0	0
Tainon	31	38	25	6
Tororo	0	50	50	0
320/07	31	69	0	0
91/316	50	44	0	6
Zapallo	100	0	0	0
Tanzania	25	69	6	0
Salyboro	63	19	0	18
Kanziga 1-1	13	63	13	11
Mogamba	100	0	0	0
Kanziga 2-1	88	12	0	0

Table 4: The farmers perception (in %) on the taste of different sweetpotato cultivars grown in Makueni (Kampi ya Mawe) District, Kenya, during the 2001/2002 cropping season.

Cultivar	Taste (%)			
	Good	Acceptable	Not acceptable	Undecided
316/02	25	50	25	0
320/06	19	25	0	56
Naveto	19	31	0	50
Bikiramaria	75	25	0	0
Cemsa	0	56	19	25
192100/103	44	31	0	25
Tainon	0	81	0	19
Tororo	0	0	44	56
320/07	0	81	0	19
91/316	6	38	25	31
Zapallo	31	31	0	38
Tanzania	13	31	31	25
Salyboro	56	25	0	19
Kanziga 1-1	50	38	12	0
Mogamba	44	50	0	6
Kanziga 2-1	75	25	0	0

the appearance of the roots was important, taste finally influenced their final selection. This was taken into consideration in arriving at the overall acceptability of the cultivars. Though Kanziga 1-1 had the highest yields it was only selected as the sixth best because it was less appealing in its appearance and taste than the other better 5 cultivars.

Conclusions and recommendations

The overall cultivar selection by farmers was Kanziga 2-1, Mogamba, Bikiramaria, 192100/103, Salyboro and Kanziga 1-1. These cultivars could be multiplied and subjected to rigorous on-farm trials. The farmers' most important selection criteria were taste, appearance and yield in that order. Therefore, plant breeders should in addition to yield include taste and appearance in their selection criteria. Cultivar Kanziga 1-1 was selected as the 6th best cultivar despite being the highest yielder. Plant breeders could consider improving its appearance and taste.

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Farmers decide: A participatory approach to the development and dissemination of improved cassava technologies that increase yields and prevent soil degradation

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Abstract. Farmers in Asia like to grow cassava because the crop tolerates long dry periods and poor soils, and produces reasonable yields with little inputs. Most farmers realize, however, that cassava production on slopes can cause severe erosion, while production without fertilizer inputs may lead to a decline in soil productivity. Research has shown that cassava yields can be maintained for many years with adequate application of fertilizers, and that there are various ways to reduce erosion. Adoption of erosion control practices, however, has been minimal as farmers generally see little short-term benefits of these practices. To enhance the adoption of soil conserving practices and improve the sustainability of cassava production, a farmer participatory research (FPR) approach was used to develop not only the best soil conservation practices, but also to test new varieties, fertilization and cropping systems that tend to produce greater short-term benefits. The FPR methodology was initially developed in 2-3 sites each in China, Indonesia, Thailand and Vietnam, but has now extended to about 99 villages in Thailand, Vietnam and China. The methodology includes the conducting of RRAs in each site, farmer evaluation of a wide range of practices shown in demonstration plots, FPR trials with farmer-selected treatments on their own fields, field days with discussions to select the best among the tested practices, scaling-up to

larger fields, and farmer participatory dissemination to neighbors and other communities. Based on the results of these trials, farmers have readily adopted better varieties, fertilization and intercropping practices, and many farmers have now adopted the planting of contour hedgerows to control erosion. The resulting increases in cassava yields in Asia over the past eight years have increased the annual gross income of cassava farmers by an estimated 150 million US dollars.

Introduction

Cassava (*Manihot esculenta* Crantz) is usually grown by smallholders in upland areas with poor soils and low or unpredictable rainfall. In some countries, the crop is grown on steep slopes, but in others it is grown mainly on gentle slopes; in both cases, soil erosion can be serious. Moreover, cassava farmers seldom apply adequate amounts of fertilizers or manures to replace the nutrients removed in the harvested products. Thus, both erosion and nutrient extraction can result in a decline in soil fertility and a gradual degradation of the soil resource.

The fact that farmers do not apply sufficient fertilizers and do not use soil conservation practices when the crop is grown on slopes is more a socio-economic rather than a technical problem. Research has

shown many ways to maintain or improve soil fertility and reduce erosion, but farmers usually consider these practices too costly or requiring too much labor. To overcome these obstacles to adoption, it is necessary to develop simple practices that are suitable for the local situation and that provide short-term benefits to the farmer as well as long-term benefits in terms of resource conservation. Being highly site specific these practices can best be developed by the farmers themselves, on their own fields, in collaboration with research and extension personnel.

Thus, a project was initiated, with financial support from the Nippon Foundation in Tokyo, Japan, to develop a farmer participatory methodology for the development and dissemination of more sustainable production practices in cassava-based cropping systems that will benefit a large number of poor farmers in the uplands of Asia.

Materials and Methods

First Phase (1994-1998). The first phase of the project was conducted in four countries, i.e. China, Indonesia, Thailand and Vietnam. The project was coordinated by CIAT and implemented in collaboration with research and extension organizations in each of the four countries. During an initial training course on farmer participatory research (FPR) methodologies, each country designed a work plan to implement the project. The steps in the process, from diagnosing the problem to adoption of suitable solutions, are shown in Figure 1. The outstanding feature of this approach is that farmers participate in every step and make all important decisions.

(a) Pilot site selection. Suitable pilot sites were pre-selected in areas where cassava is an important crop, where it is grown on slopes and erosion is a serious problem. Detailed information obtained through Rapid Rural

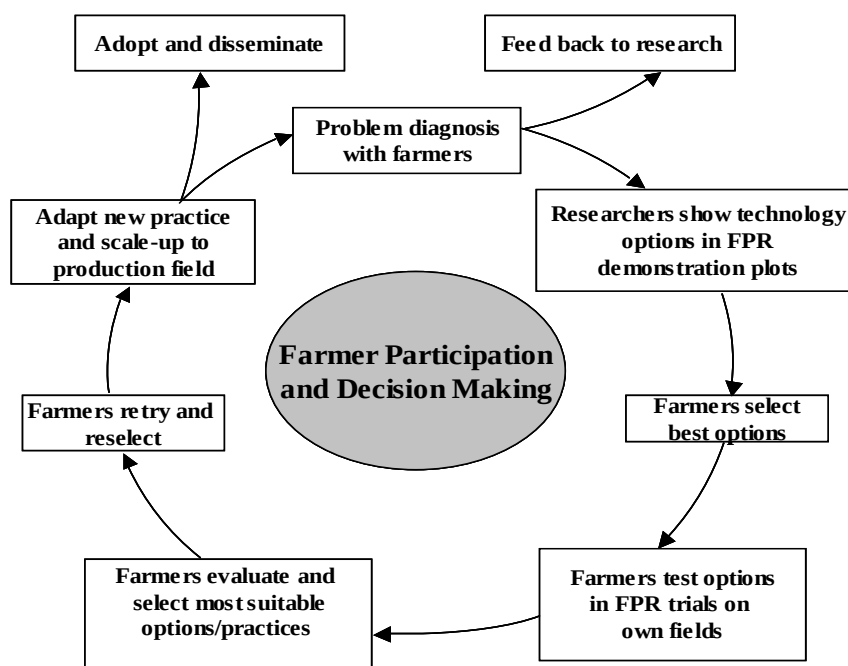


Figure 1: Farmer participatory model used for the development of sustainable cassava-based cropping systems in Asia.

Appraisals (RRA) in each site have been reported by Nguyen The Dang *et al.* (1998), Utomo *et al.* (1998), Vongkasem *et al.* (1998) and Zhang Weite *et al.* (1998). After conducting the RRAs, one or two suitable pilot sites (villages or sub districts) were selected to work with farmers in the development and dissemination of suitable varieties and production practices.

(b) Demonstration plots. Each year demonstration plots were laid out on an experimental station or a farmer's field to show the effect of many alternative treatments on yield, income and soil erosion. Farmers from the selected pilot sites visiting the trial were asked to discuss and score the usefulness of each treatment. From this range of many options farmers usually selected 3-4 treatments that they considered most useful for their own conditions. Some farmers then volunteered to test these treatments in FPR trials on their own fields.

In both the demonstration plots and FPR erosion control trials on farmers' fields, a simple methodology was used to measure soil loss due to erosion in each treatment. Plots were laid out along the contour on a uniform slope; along the lower side of each plot a ditch was dug and covered with plastic. Small holes in the plastic allowed runoff water to seep away, while eroded sediments remained on the plastic. These sediments were collected and weighed several times during the cropping cycle. After correcting for moisture content, the amount of dry soil loss per hectare was calculated for each treatment. This simple methodology gives both a visual as well as a numerical indication of the effectiveness of the various practices in controlling erosion (Howeler, 2001; 2002).

(c) FPR trials. The FPR trials did not only involve soil conservation practices, but also new varieties, intercropping systems and fertilization, with the objective of developing a combination of practices that would increase farmers' income, reduce erosion and improve soil fertility.

During the first phase of the project, farmers in the four countries conducted a total of 177 FPR erosion control trials, 157 variety trials, 98 fertilizer trials and 35 intercropping trials. At time of harvest, field days were organized in each site to harvest the various trials by the participating farmers and their neighbors. The yields of cassava and intercrops, the dry soil loss due to erosion, as well as the gross income, production costs and net income were calculated for each treatment and presented in a joint meeting to the farmers. After one or more years of testing in small plots, farmers quickly identified the best varieties and production practices for their area and started using those on larger areas of their production fields (Howeler, 2002).

Second Phase (1999-2003). The second phase of the project was conducted in collaboration with five institutions in Thailand, six in Vietnam and three in China. During the second phase the emphasis shifted from participatory research (FPR) to extension (FPE) in order to reach more farmers and achieve more widespread adoption. These farmer participatory extension activities included the organization of cross-visits, in which farmers from a "new" site visited those from an "older" (already established) site where FPR trials were being conducted or where some selected practices had already been adopted. It also included training courses for key farmers and local extensionists; farmer field days at time of harvest as well as large-scale farmer field days with participation of many farmers from the district or province, and the establishment of community-based self-help groups. In addition, more conventional extension tools, such as a video, and booklets on various aspects of cassava production and utilization were prepared.

Once farmers had selected certain practices and wanted to adopt those on their fields, the project staff tried to help them; for instance, in setting out contour lines to plant hedgerows for erosion control, or to obtain

seed or vegetative planting material of the selected hedgerow species, intercrops or new cassava varieties.

Results and Discussion

First Phase (1994-1998): Farmer Participatory Research (FPR)

(a) FPR trials. Table 1 shows a typical example of an FPR erosion control trial conducted by six farmers having adjacent plots on about 40% slope. It is clear that contour hedgerows of vetiver grass, *Tephrosia candida* or pineapple reduced erosion to less than 20% of that in the check plot, while intercropping with peanut and planting vetiver hedgerows markedly increased net income. Results of many other FPR trials have been reported by Nguyen The Dang *et al.* (2001), Huang Jie *et al.* (2001), Utomo *et al.* (2001) and Vongkasem *et al.* (2001).

(b) Scaling-up and adoption. After having selected the most promising varieties and production practices from FPR trials, farmers generally like to test some of these on small areas of their production fields, making adaptations if necessary. Some practices may look promising on small plots, but are rejected

as impractical when applied on larger areas; this may be due to lack of sufficient planting material (like vetiver grass) or lack of markets for selling the products (like pumpkin or lemon grass).

Second Phase (1999-2003): Farmer Participatory Research (FPR) and Extension (FPE)

Since the objective of the second phase was to achieve widespread adoption of more sustainable production practices by as large a number of farmers as possible, it was necessary to markedly expand the number of pilot sites and to develop farmer participatory extension (FPE) methodologies to disseminate the selected practices and varieties to many more farmers.

In subsequent years, the project was expanded. In 2001 the project was being implemented in about 50 sites. This was further increased to 99 sites by the end of the project in 2003 (Figure 2). Once the benefits of the new technologies became clear, the number of sites increased automatically, as neighboring villages also wanted to participate in order to increase their yields and income.

Whenever the project extended to a “new” site, the process outlined above was re-

Table 1: Results of an FPR erosion control trial conducted by six farmers in Kieu Tung village, Thanh Ba district, Phu Tho, Vietnam, in 1999.

Treatment ¹	Slope (%)	Dry soil loss (t/ha)	Yield (t/ha)		Gross income ²	Product costs ³	Net income
			cassava	Peanut			
_____ (mil. dong/ha) _____							
1. C monocult., with fertilizer, no hedgerows	40.5	51.8	26.3	-	10.52	3.04	7.48
2. C+P, no fertilizer, no hedgerows	45.0	25.1	11.5	0.45	7.07	4.45	2.62
3. C+P, with fertilizer, no hedgerows	42.7	33.7	18.6	0.47	10.02	5.26	4.76
4. C+P, with fertilizer, <i>Tephrosia</i> hedgerows	39.7	6.2	23.8	0.49	12.21	5.26	6.95
5. C+P, with fertilizer, pineapple hedgerows	32.2	10.5	24.0	0.66	13.23	5.26	7.97
6. C+P, with fertilizer, vetiver hedgerows	37.7	8.0	33.8	0.37	15.55	5.26	10.29
7. C monocult, with fert., <i>Tephrosia</i> hedgerows	40.0	3.3	21.7	-	8.68	3.04	5.64

¹ Fertilizers = 60 kg N + 40 P₂O₅ + 120 K₂O/ha; all plots received 10 t/ha pig manure.

² Prices: cassava dong 400/kg fresh roots, peanut 5500/kg dry pods. ³ Cost fertilizers = 0.810 mil. dong/ha; cost of intercropping = 2.22 mil.dong/ha.

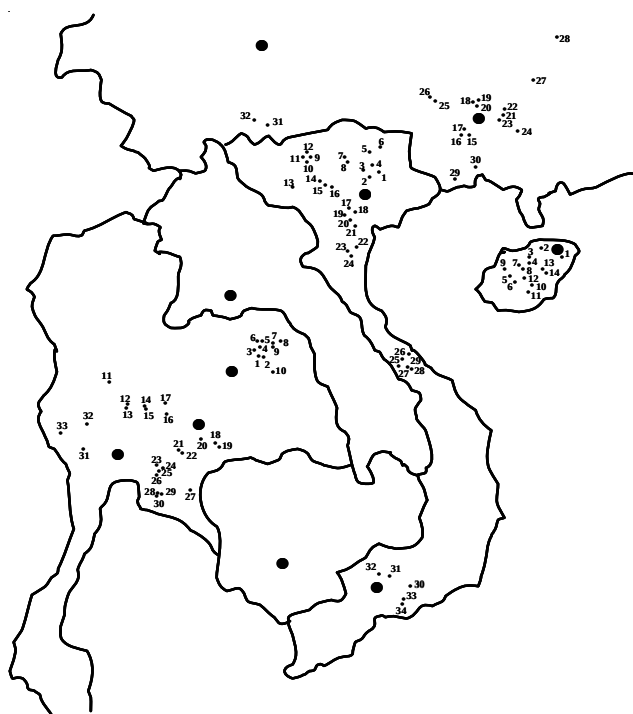


Figure 2: Location of FPR pilot sites in China, Thailand and Vietnam in the Nippon Foundation cassava project in 2003.

initiated, i.e. an RRA was conducted, interested farmers visited demonstration plots and/or made a cross-visit to an already established site, and they conducted FPR trials, discussed results and eventually adopted those varieties or practices they had selected as most suitable for their own conditions. Table 2 shows the number and type of FPR trials conducted in China, Thailand and Vietnam during the second phase of the project. While initially farmers were mainly interested in testing new varieties, fertilization, intercropping and erosion control practices, during the later part of the project they also wanted to test the use of organic or green manures, weed control, plant spacing and even leaf production and pig feeding. During the second phase of the project a total of 1,154 FPR trials were conducted by farmers on their own fields.

The following farmer participatory extension methods were found to be very effective in raising farmers' interest in soil

conservation, in disseminating information about improved varieties and cultural practices, and in enhancing adoption of soil conserving practices:

(a) Cross-visits. Farmers from new sites were usually taken to visit older sites that had already conducted FPR trials and had adopted some soil conserving technologies. These cross-visits, in which farmers from the older site could explain their reasons for adopting new technologies was a very effective way of farmer-to-farmer extension. After these cross-visits, farmers in some new sites decided to adopt some technologies immediately, while others decided to conduct FPR trials in their own fields first. In both cases, the "FPR teams" of the various collaborating institutions, together with provincial, district or sub district extension staff, helped farmers to establish the trials, or they provided seed or planting materials required for the adoption of the new technologies.

Table 2: Number of FPR trials conducted in the 2d phase of the Nippon Foundation Project in China, Thailand and Vietnam.

Country	Type of FPR trial	1999	2000	2001	2002	2003	Total
China	Varieties	9	9	20	69	20	127
	Erosion control	3	5	8	17	-	33
	Fertilization	-	-	-	4	-	4
	Intercropping	-	-	-	9	-	9
	Pig feeding	-	-	-	59	-	59
		12	14	28	158	20	232
Thailand	Varieties	11	16	16	19	25	87
	Erosion control	14	10	6	-	11	41
	Chemical fertilizers	16	6	23	17	17	79
	Chem.+org fertilizers	-	-	10	11	11	32
	Green manures	-	-	13	11	15	39
	Weed control	-	-	17	5	10	32
	Plant spacing	-	-	3	-	2	5
	Intercropping	-	-	16	7	-	23
		41	32	104	70	91	338
Vietnam	Varieties	12	31	36	47	35	161
	Erosion control	16	28	29	30	23	126
	Fertilization	1	23	36	24	24	108
	Intercropping	-	14	32	31	26	103
	Weed control	-	3	-	-	3	6
	Plant spacing	-	1	7	19	8	35
	Leaf production	-	-	2	2	1	5
	Pig feeding	-	-	11	16	13	40
		29	100	153	169	133	584
Total		82	146	285	397	244	1,154

(b) Field days. At time of harvest, field days were organized at the site in order to harvest the trials and discuss the results. Farmers from neighboring villages were usually invited to participate in these field days, to evaluate each treatment in the various trials and to discuss the *pros* and *cons* of the various practices or varieties tested. In a few cases, large field days were also organized with participation of hundreds of neighboring farmers, school children, local and high-level officials, as well as representatives of the media. The broadcasting or reporting about these events also helped to disseminate the information about suitable technologies. During the field days, farmers explained the results of their own FPR trials to the other

visiting farmers, while literature about the project and the results obtained was distributed.

(c) Training. Research and extension staff involved in the project had previously participated in Training-of-Trainers courses in FPR methodologies, including practical training sessions with farmers in some of the pilot sites. While some participants were initially skeptical, most course participants became very enthusiastic about this new approach once they started working more closely with farmers.

In addition, 2-3 key farmers from each site together with their local extension agent were invited to participate in FPR training courses.

The objective was to learn about the various FPR methodologies, the basics of doing experiments as well as the implementation of commonly selected technologies, such as setting out contour lines or the planting, maintenance and multiplication of hedgerow species. By spending several days together in these courses, the farmers and extensionist got to know each other well, and they were encouraged to form a local “FPR team” to help other farmers in their community conduct FPR trials or adopt the new technologies.

(d) Community-based self-help groups.

Realising that effective soil conservation practices, such as planting of contour hedgerows, can best be done as a group, farmers from some sites decided to form their own “soil conservation group”. These community-based self-help groups are similar to “Land Care units”, that have been very effective in promoting soil conservation in the Philippines and Australia. In Thailand, farmers are encouraged farmers to set up these groups as a way of organizing themselves, to conduct FPR trials, to implement the selected practices, and to manage a rotating fund, from which members of the group can borrow money for production inputs. Thus, by 2003, a total of 21 “Cassava Development Villages” had been set up in the pilot sites. Each group needed to have at least 40 members, elect five officers to lead the group, and establish their own bylaws about membership requirements, election of officers, use of the rotating fund, etc. The formation of these groups helped to decide on collective action and to strengthen the community, while people gained confidence and the group became more self-reliant. When necessary, the group could request help from local or national extension services, obtain information about certain production problems, or get planting material of vetiver grass or other species for hedgerows or green manures. Some groups started their own vetiver grass nurseries to have planting material available when needed.

(e) Adoption and Impact. After conducting their own FPR trials, or after a cross-visit to another village where those trials were being conducted, farmers often decided to adopt one or more technologies on their production fields with the hope of increasing yields or income and protecting the soil from further degradation.

In Thailand, practically all of the cassava area is now planted with new varieties and about 75% of farmers apply some chemical fertilizers (TTDI, 2000), although usually not enough nor in the right proportion. As a result of the FPR fertilizer trials, farmers started to apply more K, while the official fertilizer recommendation for cassava was changed from an NPK ratio of 1:1:1 to 2:1:2. After trying various ways of controlling erosion, most farmers selected the planting of vetiver grass contour hedgerows as the most suitable. Table 3 indicates that by the end of 2003, about 865 farmers had planted a total of 1.65 million vetiver plants, corresponding to about 150 km of hedgerows.

Table 4 similarly summarizes the adoption of various new technologies in Vietnam. In 2001, over 1400 farmers in the FPR pilot sites were planting new cassava varieties (mainly KM 94), while hundreds were applying more balanced fertilization (usually pig manure in addition to chemical fertilizers), intercropped with peanut or black bean, and controlled erosion by the planting of contour hedgerows of *Tephrosia candida*, vetiver grass or *Paspalum atratum*. In some villages in Pho Yen district of Thai Nguyen province in North Vietnam, the gross income of many farmers in 2001 was 4-5 times higher than those reported in 1994/95 at the start of the project (CIAT, 2001). During 2002 and 2003 farmers in Van Yen district of Yen Bai province in North Vietnam planted a total of 500 km of double hedgerows of *Tephrosia candida* or *Paspalum atratum* to control erosion, and they planted about 3000 ha of new cassava varieties with improved fertilizer practices. This increased average yields from 10 t/ha to about 30 t/ha.

Table 3: Extent of adoption of vetiver grass contour hedgerows for erosion control in various FPR pilot sites in Thailand in 2003.

Province		District	Sub district	Adoption of vetiver grass			
				Cassava		Vetiver	
				No. of farmers	area with vetiver (ha)	(no. of plants)	hedgerows (km) ¹⁾
1.	Kalasin	Mueang	Phuu Po	61	49.0	85,500	8.6
2.	Kalasin	Mueang	Khamin	-	-	-	-
3.	Kalasin	Nong Kungsri	Nong Bua	67	110.4	111,600	11.2
4.	Kalasin	Sahatsakhan	Noonburi	63	59.2	86,170	8.6
5.	Kalasin	Sahatsakhan	Noon Nam Kliang	47	40.6	128,330	12.8
7.	Kalasin	Naamon	Naamon	50	24.0	56,000	4.0
8.	Kalasin	Huay Phueng	Nikhom	50	24.0	216,000	20.0
9.	Kalasin	Don Chaan	Dong Phayung	50	24.0	28,500	2.2
10.	Roy Et	Phoo Chai	Khampha-ung	-	-	4,000	0.4
11.	Kamphaengphet	Khanuwaralakburi	Bo Tham	42	27.2	68,000	3.0
12.	Chayaphum	Thep Sathit	Naayaang Klak	42	27.2	83,000	5.5
14.	Nakhon Ratchasima	Thepharak	Bueng Prue	-	-	-	-
15.	Nakhon Ratchasima	Thepharak	Bueng Prue	26	34.2	80,000	11.0
16.	Nakhon Ratchasima	Sri Khiw	Paang Lako	-	-	-	-
17.	Nakhon Ratchasima	Daan Khun Thot	Baan Kaw	53	49.4	130,000	15.0
18.	Nakhon Ratchasima	Soeng Saang	Noon Sombuun	62	132.5	80,000	20.0
19.	Nakhon Ratchasima	Soeng Saaang	Sratakhan	-	4.8	20,000	2.0
20.	Nakhon Ratchasima	Khonburi	Tabaekbaan	27	24.0	100,000	5.0
21.	Prachinburi	Naadii	Kaeng Dinso	34	27.2	60,000	4.5
23.	Chachoengsao	SanaamChaikhet	Thung Prayaa	32	10.4	50,000	2.0
24.	Chachoengsao	Thaa Takiap	Khlong Takraw	42	27.2	100,000	5.3
27.	Sra Kaew	Wang Sombuun	Wang Sombuun	75	220.8	90,000	9.0
28.	Chonburi	Bo Thong	Kaset Suwan	-	-	-	-
31.	Ratchaburi	Baan Poong	Khaw Khalung	-	-	-	-
32.	Kanchanaburi	Law Khwan	Thung Krabam	42	27.2	80,000	3.0
33.	Kanchanaburi	Sai Yook	Sai Yook	-	-	-	-
Total	11	22	25	865	943.3	1,657,100	153.1

¹⁾Cassava area with hedgerows and hedgerow length are approximate, as some hedgerows were damaged by tractor while others needed to be partially replanted because of poor establishment due to drought.

Table 5 indicates the extent of adoption of new varieties in China, Thailand and Vietnam, both in terms of cassava area planted and the number of farmers planting these varieties. Only a fraction of the more than 800,000 farmers planting new varieties had actually participated in the project; the others must have heard about new varieties from extension agents, other farmers, starch factories or TV. In Thailand about 98% of the total cassava area is now planted with new varieties; in Vietnam this is about 40% and in China about 10%. Table 6 shows that during the past eight years the average cassava yields in all three

countries increased; this increase ranged from 0.83 t/ha in China to 4.16 t/ha in Vietnam. The increased yields resulted in annual increases in gross farmers' income by about 100 million US dollars in the three countries, and about 150 million US dollars in the whole of Asia. In addition, farmers in Thailand received higher prices due to the higher starch content of the new varieties. This was achieved by the collaborative effort of many researchers, extensionist, factory owners and farmers with strong support from national governments. The development of high yielding improved varieties and more efficient agronomic and soil

Table 4: The adoption of new technologies by farmers in various sites in Vietnam in 2001.

Province	District	Village	Adoption (no. farmers/ha)				
			Varie- ties	Fertili- zation	Erosion control	Inter- cropping	Silage making
Thai Nguyen	Pho Yen	Tien Phong	81/4.7	45/2.3	4/0.2	40/1.5	-
		Dac Son	22/0.7	15/0.8	3/0.1	8/0.5	-
		Minh Duc	30/0.9	25/0.7	3/0.3	25/1.6	-
		Hong Tien	26/1.0	-	-	-	-
		Van Phai	26/0.3	-	-	-	-
		Nam Tien	7/0.2	-	-	-	-
Thuong Am commune							
Tuyen Quang	Son Duong	Am Thang	16/2.0	15/0.5	15/6.0	-	-
		Hong Tien	18/1.2	18/0.6	8/4.0	-	-
Yen Bai	Van Yen	Yen Hung	5/2.0	-	5/2.0	-	-
		Yen Thai	4/2.0	-	4/2.0	-	-
		Yen Hop	6/2.0	-	6/2.0	-	-
		Mau Dong	9/4.0	-	9/2.0	-	-
		Dong Cuong	7/2.0	-	7/2.0	-	-
		Tan Hop	5/2.0	-	5/2.0	-	-
		Dong An	6/2.0	-	6/2.0	-	-
		Lam Giang	4/2.0	-	4/2.0	-	-
		An Binh	7/2.0	-	7/2.0	-	-
Phong Linh commune							
Phu Tho	Thanh Ba	Kieu Tung	13	-	25	-	-
Thong Nhat commune							
	Phu Ninh	Thong Nhat	32/2.0	-	25/3.5	-	-
		Bao Thanh	5	-	-	2	-
Dong Xuan commune							
Hao Binh	Luong Son	Dong Rang	-	12	45	9	-
Ha Tay	Thach That	Thach Hoa	1000/ 100	10	15	4	-
Tran Phu commune							
Chuong My	Tran Phu	40	-	-	60	-	
Thua Thien-Hue	A Luoi	Hong Ha	>19	12	25	>20	15
Nam Dong	Thuong Long	10	-	-	-	20	
Huong Tra	Huong Van	-	-	-	-	40	
Dong Nai	Thong Nhat	An Vien	>30	2	-	5	-
Binh Phuoc	Dong Xoai	Dong Tam	-	5	-	5	-
		Minh Lap	-	10	-	5	-
Baria Vungtau	Chau Duc	Suoi Rao	7/1.4	-	5/2.0	-	-
Total		30	>1,435	169	226	>183	75

Table 5: Estimation of the number of farmers that have adopted and benefited from new cassava varieties in China, Thailand and Vietnam.

Country	Province	Average cassava areaper household(ha) ¹	Area undernew varieties (ha)	Average no.of farmers adopting new varieties ²
China	Guangxi	0.22	16,666	75,500
	Guangdong	0.53	~6,000	~11,320
	Hainan	0.53	1,333	2,500
Thailand		2.86	1,000,000	350,000
Vietnam		0.27	100,000	370,000
Total				~809,320

¹Data estimated from RRA (1994) and Vietnam Cassava Survey (1991/92)

²Assuming complete replacement of old by new varieties.

Table 6: Estimation of the annual increase in gross income due to higher cassava yields resulting from the adoption of new cassava varieties and improved practices, in China, Thailand and Vietnam, as well as in Asia as a whole.

Country	Total cassava area	Cassava yield (t/ha) ¹		Yield increase	Cassava price	Increased gross income due to higher yields
	(ha) ¹	1994	2002	(t/ha)	(\$/tonne)	(mil. US \$)
China	240,100	15.21	16.04	0.83	24-30	5.4
Thailand	1,030,000	13.80	16.38	2.58	21-24	59.8 ²
Vietnam	329,900	8.44	12.60	4.16	22-29	35.0
Asia total	3,486,502	12.93	14.67	1.74	25	151.7

¹Data from FAOSTAT 2003.

²In addition, farmers also benefited from higher prices due to higher starch content.

conservation practices, as well as the use of a farmer participatory approach, all contributed to the widespread adoption of new varieties and improved practices in many countries in Asia resulting in improved livelihoods of cassava farmers.

Conclusions

Research on sustainable land use conducted in the past has mainly concentrated on finding solutions to the bio-physical constraints, and many solutions have been proposed for improving the long-term sustainability of the

system. Still, few of these solutions have actually been adopted by farmers, mainly because they ignored the human dimension of sustainability. For new technologies to be truly sustainable they must not only maintain the productivity of the land and water resources, but they must also be economically viable and acceptable to farmers and the community. To achieve those latter objectives farmers must be directly involved in the development, adaptation and dissemination of these technologies. A farmer participatory approach to technology development was found to be quite effective in developing

locally appropriate and economically viable technologies, which in turn enhances their acceptance and adoption by farmers.

The conduct of FPR trials is initially time consuming and costly, but once more and more people are trained and become enthusiastic about the use of this approach - including participating farmers - both the methodology and the selected improved varieties or cultural practices will spread rapidly. The selection and adoption of those farming practices that are most suitable for the local environment and in tune with local traditions will improve the long-term sustainability of the cropping system, to the benefit of both farmers and society at large.

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Nutrition and utilization of a new sweetpotato cultivar for tops

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Abstract. A new variety, Suioh, was released for vegetable use by the National Agricultural Research Center for Kyushu Okinawa Region, Japan in 2001. The nutritional value of the flour made from the tops of Suioh and the characteristics of its processed foods, bread and green tea, were evaluated to develop a new use of sweetpotato tops. The protein, lipid, sodium, iron, zinc, carotene, total ascorbic acid, vitamin E, and vitamin K₁ contents were the highest in the leaves. The highest content of ash, potassium and carbohydrate were the highest in petioles or stems. The dietary fiber, energy, phosphorous and magnesium contents did not much differ among the portions. The contents of the components in each portion of the tops in the Jul. 15 harvests did not change appreciably in Aug. 27 harvests. The flour from whole tops, consisting of leaves, petioles and stems, seemed to have a well-balanced nutritional value. Addition of flour from whole tops at 2% of the bread ingredients was the optimal amount for swelling, color, hardness and bread aging in bread processing. The green tea made from the tops contained high amount of polyphenols and showed high activity of radical scavenging activity. Thus, sweetpotato tops can be used as an ingredient of processed foods and green tea in addition to its use as a leafy vegetable.

Introduction

Sweetpotato (*Ipomoea batatas* L.) has long been an important crop in Japan. Its tuber can be processed into foods, starch, juice and

alcoholic beverages, in addition to table use (Yamakawa, 2002). Recently, some researches on the beneficial physiological functions of sweetpotato tuber have been reported (Yoshimoto *et al.*, 1999; Suda *et al.*, 2002). On the other hand, sweetpotato tops have limited use compared to the tubers. The tops were used as a vegetable during famine in Japan. A small amount of tops, however, has only been used as an animal feed or as a green manure in recent years, except for a few provinces where tops are used as a vegetable. Sweetpotato tops, however, have much potential as food, because their protein, vitamins and minerals are comparable to other commercial vegetables (Woolfe, 1992). The tops also contain much higher level of polyphenols, which have many physiological functions, than other commercial vegetables (Islam *et al.*, 2002). Therefore, sweetpotato tops seem to be a suitable vegetable for summer when most leafy vegetables are scarce in the market. There is only one cultivar, however, that has good taste petioles in Japan. Thus, we have developed a new sweetpotato cultivar Suioh whose tops are acceptable as a vegetable.

In this paper, we produced flours from the leaves, petioles and stems of the new cultivar and analyzed their nutritional value. We also processed bread and green tea to increase the product range of sweetpotato tops. The appropriate amount of flour as an additional ingredient in bread processing was determined and the polyphenol content as well as its physiological function as a radical-scavenging nutrient of the tea were evaluated.

Materials and Methods

Cultivation. Sprouts produced from storage roots of Suioh were transplanted to two blocks in an experimental field in Upland Farming Research, the National Agricultural Research Center for Kyushu Okinawa Region in April 2002. Twenty sprouts were transplanted into each block at a spacing of 0.75 x 0.35 m. A fertilizer mixture (48.0 kg N, 31.5 kg P, 99.6 kg K per hectare) and compost (10 t/ha) were applied to the soil before planting. First harvesting of tops was done in July 2002. Then more fertilizers in form of a mixture (48.0 kg N, 31.5 kg P, 99.6 kg K per hectare) and ammonium sulfate (106 kg N/ha) were applied in August. The tops were cut at five cm from the ground level in both harvesting.

Flour processing and nutrition. The harvested tops from 10 plants (five plants per block) were separated into leaves, petioles, and stems. The samples were washed and frozen at -35 °C for a few days. The frozen samples were dried in vacuo using a freeze drier (model TR-PK-3-80, Trio Sciences), milled, and the flours kept in a freezer at -35 °C until use. The protein, lipid, ash, carbohydrate, dietary fiber, energy, mineral [sodium (Na), phosphorous (P), iron (Fe), calcium (Ca), potassium (K), magnesium (Mg) and zinc (Zn)], and vitamins (carotene, total vitamin C, vitamin E and vitamin K₁) contents of the flours were analyzed by the Japanese Food Research Laboratories.

Processing of bread. The Bread-mix (SD-MIX100, Nissin Foods), consisting of wheat, sugar, vegetable oil, skim milk and salt, and dry yeast, was used in making bread. The flour produced from whole tops was sieved through the 100 mm sieve and used as an ingredient in the bread. Two hundred ml of water was added to 315 g of the Bread-mix, 2.7 g of dry yeast with either 0 g (control), 6.3 g (2% of the weight of bread mix), 12.6 g (4%) or 18.9 g (6%) of the flour and they were set to Home Bakery (SD-BT6, National). The total processing time was 4 h and 15 min. The top height of baked breads

was measured as an index of swelling, and the color value was determined by a colorimeter (CR-221, MINORTA). The bread was cut into four pieces (3 x 2 x 2 cm) and its hardness was measured by Digital force gauge (FGC-2, SIMPO) at 0 (the day of baking), 1 and 2 d after storage. Two-way analysis of variance for the amount of flour added to the bread mix and storage duration of the bread was analyzed and the means of four replicates were compared using the least significant difference (LSD).

Processing of sweetpotato green tea. The harvested tops were washed well and steamed for 5 min. After cooling and withering, the tops were chopped into tiny pieces, kneaded, and dried at 80°C. The total content of polyphenols, extracted by hot water (100°C), was measured according to the Folin-Ciocalteu method, with a slight modification (Islam *et al.*, 2002). The procedure used by Brand-Williams *et al.* (1995) for evaluating the radical scavenging activity was followed with a slight modification. Fifty ml of the sweetpotato green tea, extracted by hot water, was transferred into a 96-well micro plate, then 50ml of 200mM MES buffer (pH 6.0), 50 ml of 20 % ethanol and 50 ml of 800mM 1,1-diphenyl-2-picrylhydrazyl (DPPH) solution (in ethanol) were added. After 20 min, the absorbances of the reaction mixture and standard Trolox were measured at 520 nm.

Results and Discussion

Flour nutrition. Flours made from the leaves, petioles, and stems of Suioh tops both in July and August in 2002 harvests were prepared by freeze drying, and their nutritional values evaluated. The protein, lipid, sodium, iron, zinc, carotene, total ascorbic acid, vitamin E and vitamin K₁ contents were the highest in the leaves. The highest content of ash, potassium and carbohydrates were in petioles or stems. Dietary fiber, energy, phosphorous and magnesium contents did not differ much among the portions. The contents of the components in each part of the tops in the

both harvests did not change appreciably. The nutritional value of whole tops was calculated by dry matter distribution of the leaves, petioles and stems. Based on the estimated value, the flour from whole tops contained a well-balanced nutrition, indicating that it can be a good ingredient for processed foods.

Processing of bread. The flour made from whole tops was used for bread processing. The top height of the bread containing the flour decreased as added amount increased, although there was no difference between 0% (control) and 2% addition. The L* value of the bread decreased and a* value increased as added amount increased, although a* value of 2 % addition was lower than that of the control. b* value increased until 4% but decreased at 6% addition. Although 2% addition of tops flour was acceptable in color, the color of 4 % and 6 % addition were too dark. Hardness of bread was measured at 0 (the day of baking), 1 and 2 d after storage. Two-way analysis of variance showed significant difference among added amount of tops flour and storage period. The hardness of the bread did not differ between control and addition of tops flour at 2% of the bread mix but significantly increased at 4% and 6%. As storage time increased, bread hardened significantly, but the hardness of 2 % added bread was lower than those of 4 % and 6 % addition and did not differ with that of the control. From these results, 2 % addition of tops flour to bread ingredients was the optimum amount for better swelling, color, hardness and bread aging in bread processing.

Processing of sweetpotato green tea. Sweetpotato tops were processed into green tea using the methods of processing green tea from tea plants. The tea extracted by hot water was yellowish green with a good taste. The total polyphenol content of sweetpotato green tea was 17.6 mg chlorogenic acid equivalent per gram and DPPH radical scavenging activity was 57.6 μ mol Trolox equivalent per gram. Since the polyphenol oxidase became inactive during steaming,

most of the polyphenol in tops would have been maintained through processing. Green tea is the most popular drink in Japan, therefore, sweetpotato green tea would be easily accepted and might prevent a lot of diseases related to radicals by the function of the polyphenols.

Implications

We processed the flour using tops of the new cultivar for tops utilization. The leaves were the best nutritionally, but the flour from whole tops was estimated to have well-balanced nutrition and was a good ingredient for making bread. The flour could be used for other processed foods, such as noodles, pudding, jelly, candy, cookies and a nutrition supplement for health. Sweetpotato green tea, which had much content of polyphenols and radical scavenging activity, was also processed. This might be accepted to the people mindful of their health or having any diseases. The potential for more product development from sweetpotato tops is high and we will pursue it further.

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The role of community based organisations, NGOs and farmers in technology transfer

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Abstract. Cassava (*Manihot esculenta* Crantz) and sweetpotato (*Ipomoea batatas*) are key food crops in Tanzania in general and in the lake zone in particular. Cassava and sweetpotato are household food security crops in addition to being a source of household income. Availability of the new improved varieties to farmers has been a problem in Tanzania. A project was initiated to transfer improved varieties of both cassava and sweetpotato in the lake zone to farmers. In collaboration with community-based organisations (CBOs), non-government organisations (NGOs) and farmer groups, the project distributed different varieties of cassava and sweet potato in Shinyanga and Mwanza regions through CIP/ASARECA. The CBOs, NGOs and farmer groups were very instrumental in facilitating the delivery of improved varieties to farmers. Through this informal seed delivery system using CBOs, NGOs, and farmers groups, farmers have been able to access, use and adopt improved varieties suitable for their areas. The project has also established a system that can be used for future technology transfer activities. Through this system more than 988,000 and 1,752,711 cuttings of improved cassava and sweet potato varieties, respectively, were distributed in three regions of the lake zone. The distribution activity went hand in hand with training of farmers in rapid multiplication techniques of planting materials.

Introduction

Cassava and sweet potato are the most important roots and tuber crops in the lake

zone and in Tanzania in general. The crops are grown mainly for home consumption with the excess sold to generate income. In Tanzania, the major growing areas are found in the lake zone while in southern zone the major producing regions are Mtwara, Lindi and Ruvuma. Other important production areas are Tanga and Kigoma (Msabaha and Rwenyagira, 1989). Sweet potato is grown almost everywhere in the country although production differs from one place to another.

With the outbreak of cassava mosaic disease, the need for planting materials especially in the Lake Zone of Tanzania has become great. This has triggered the need to have a system for multiplying and distribution of clean planting materials. In 1999, the ASARECA-CIP technology transfer project was initiated in the lake zone. The aim of the project was to multiply and distribute to farmers improved varieties of both cassava and sweet potato that combine resistance to major biotic stresses and other desirable traits. The project also aimed at establishing a system that could be used for future technology transfer activities.

Methodology

The project recognised and involved farmers in the project. Farmers selected fields for multiplying the crops. From these fields, planting materials were harvested and distributed to individual farmers within the group for further multiplication. At harvest individual farmers retained 50% of the planting materials for further multiplication. The rest of the materials was given to other members

of the group. This arrangement was facilitated by a formal contract between the project and individual farmers. The project involved six partners from different organizations. These partners are described below:

Plan international (Mwanza Branch). This NGO is involved in agriculture, youths, education and health. Its main role was to purchase and distribute sweet potato planting materials around Mwanza Municipality. It also supervised farmer groups and organized training for extension staff and farmers.

CARE International (Magu district). This is an NGO involved in agriculture. Their role was to organize farmers in establishing village secondary multiplication sites. The NGO purchased and distributed cassava and sweet potato from the research station and also facilitated the training of both extension staff and farmers.

Bukoba District Rural Development Programme (BDRDP). This organisation concentrate on activities that aim at improving household food production in Bukoba. In this project, its role was to establish secondary multiplication plots at farmer extension centres (FECS). It also purchased and distributed sweet potato and cassava planting materials.

International Potato Centre (CIP). The main role of CIP was to provide technical backstopping on project planning and regular monitoring of the project.

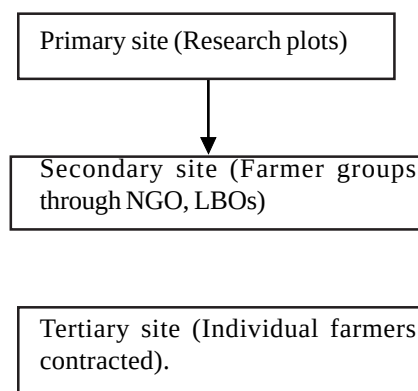
Tanzania Home Economics Association (TAHEA). This is a local NGO which is involved in household food security and agricultural technology transfer activities. Its role was to organize secondary multiplication sites and prepare training programs for farmers.

Masalakulangwa (CBO). This is a community based organisation which is

involved in both agricultural and environmental activities. Members were involved in multiplication and distribution of planting materials.

Achievements. Farmers in the project area now have access to improved varieties of both sweet potato and cassava. The widely adopted cassava varieties are: TMS 4(2) 1425, Msitu Zanzibar, and TMS 83/01762 (b) while for sweet potato, the adopted varieties include SPN/0 (simama), sinia and mavuno SP/93/94.

Farmers now earn money from the sale of both roots and planting materials. This is the first record of farmers earning money from planting materials in the zone. Another achievement of this project was the establishment of a system of multiplication and distribution of planting materials for the two crops and will be exploited for future technology transfer activities. The system is summarised below:



This system creates a sense of variety ownership by farmers and increases the chances of variety adoption. Linkage with various stakeholders has been strengthened. These linkages enhanced cost sharing, and thus made technology transfer overall cheaper.

Lessons learned. Some important lessons were learnt from this project. Increased food

production without market outlets can defeat the whole purpose of introducing improved technologies. Therefore sub-sector analysis is important before embarking on a large – scale multiplication of planting materials. This analysis will identify constraints and find solutions early enough. When farmers get involved in all stages of the project, they get a sense of ownership which makes them committed to the technology and promotes sustainability of the technology. Market forces can change cultural traditions. The high demand for planting materials of improved varieties encouraged farmers to pay for these materials. This resulted into farmers earning some income and motivated them to grow large areas and hence increasing the chances of wide distribution of improved varieties.

Recommendation

A holistic integrated approach linking farmers to market must be adopted to make technology transfer effective and sustainable.

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Substitution of hominy meal with cassava root meal as a source of energy for growing dairy heifers

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Abstract. An experiment was carried out to evaluate the effect of cassava (*Manihot esculenta*) root meal (CRM) and fish wastes (FW) on the growth of dairy heifers in four rations. The rations were TR₁ (66.5 % HM and 31.5 % CSC) TR₂ (50 % CRM and 48 % CSC) TR₃ (67.5 % HM and 30.5% FW) and TR₄ (51.5 % CRM and 46.5 % FW). Twenty Ayrshire heifers (average weight 145±8 kg) were randomly allocated to the four rations in a completely randomized block design. Data was collected on dry matter intake (DMI), weight gain, glucose, Ca, P and protein blood levels. No difference (P>0.05) in weight gain was observed between heifers on TR₁ and TR₃. Heifers on TR₂ showed faster growth rates (P< 0.05) than those in other treatments (i.e. 620 versus 490, 460 and 410 g for TR₁, TR₃ and TR₄ respectively). Correspondingly heifers on TR₂ had superior (P< 0.05) feed efficiency (0.116) followed in a descending order by TR₁, TR₃ and TR₄ (0.097, 0.092 and 0.085 kg gain / kg feed. Heifers receiving diets containing FW had higher (P<0.05) Ca and P than those on CSC. Blood glucose and plasma protein were higher (P<0.05) in heifers receiving TR₁ (97.07g/l and 3.3 mmol/l) than those on TR₂ (94.86 g/l and 3.0 mmol/l). It is concluded that CRM could be used alone as energy source when combined with protein rich feeds like CSC and FW.

Introduction

In Tanzania, poor pre-and post-weaning performance in dairy heifers has been cited as one of the major reasons for delayed

puberty and slow herd growth (Kurwijila, 1976). The overall effects of underfeeding are high pre-weaning mortalities (8-20 %) and poor post-weaning growth rates (Kifaro *et al.*, 1987) and thus longer rearing periods before weaning and age at first breeding (Kimambo *et al.*, 1990; Kasongo *et al.*, 1995; Mohamed, 1998). Supplementary feeding of heifers with energy and protein rich feeds is therefore necessary to avoid such situations.

The common energy and protein supplements for growing ruminants on medium and large scale dairy farms in Tanzania are maize bran/hominy meal, cotton and sunflower seed cakes and forage legumes (Lekule, 1990). However, supplementary feeding of livestock is rarely done in most smallholder dairy farms as the price of concentrates is high and often beyond the purchasing power of the farmers (Shem, 1993). A good example is the unavailability of cotton seed cake due its higher export markets in neighbouring countries. Another constraining factor is the low production and competition for cereals from human beings and monogastric animals. This has led to vigorous efforts to look for other alternative feeds for ruminants including cassava root meal (CRM) and fish wastes (FW) (Israel, 1986; Katakweba, 2002).

Cassava root meal is an excellent energy source for livestock (Wanapat, 1999; Sommart *et al.*, 2000; Kanjanapruthipong *et al.*, 2001). It is however, low in dry matter, protein, fat and minerals and high in amylopectin containing starch (Lekule, 1990). It can completely replace cereals in pig rations

(Lekule, 1990, Israel (1992) and provide fermentable non-fiber carbohydrates for efficient rumen microbial growth (Kanjaputhipong *et al.*, 2001).

Research in Tanzania shows that CRM could replace 50% of maize in lactating dairy cattle rations without decreasing milk production and at much lower production cost per litre of milk (Shem *et al.*, 2003) especially when fed in combination with cotton seed cake (CSC) and other protein feed including those of animal origin. Protein of animal origin like fishmeal and especially fish wastes (FW) are abundant from the fish processing industries around Lake Victoria but are expensive and often are of inconsistent quality and supply (Katakweba, 2002). This state of affairs has greatly contributed to its underutilization in livestock feeding.

Although research in other countries show that FW use in livestock rations is economically viable (Zinn and DePeters, 1991; McDonald *et al.*, 1998), there is no much data on their use in practical livestock feeds in Tanzania unlike on sardines in poultry rations (Mbamba, 2000). The few existing reports on Nile perch FW use are based on laboratory evaluations (Ngate, 1997) or on the use of marine FW in non-ruminant feeding trials (Mohamed, 1998; Mbamba, 2000). The latter author reported positive growth rates and high feed conversion efficiency in broiler chicken fed on ration containing marine FW.

This study was therefore, carried out with the general objective of assessing the substitution effect of cassava root meal for hominy meal and cotton seed cake with Nile perch FW, respectively, on the growth performance of growing dairy heifers.

Materials and Methods

Study location. The experiment was carried out at Magadu dairy farm, Sokoine University of Agriculture (SUA) in Morogoro, Tanzania. Morogoro lies about 550m above sea level and experiences a hot climate throughout most of the year. The average humidity is

about 78 % and the temperature ranges between 20 °C and 35 °C.

Experimental animals and their management.

A total of 20 Ayrshire heifers with an average liveweight of 145±8 kg were used in the experiment. The animals were housed in individual pens and allowed free access to drinking water. They were de-wormed monthly using Levamisole (Hoonspraten Ltd Belgium) injectable solutions (1ml/10 kg liveweight). External parasites were controlled using a pour on acaricide (Pyrethrins) (Coopers Ltd., Nairobi Kenya) at a rate of 1ml/20 kg live weight every 3 weeks. The animals were also fed multivitamins (Hoonspraten Ltd Belgium) at 1ml/10 kg live weight at also every 3 weeks also.

Feeds and feeding. All the animals were fed on a basal diet of hay dominated by *Brachiaria brizantha* supplemented with CRM and HM and FW or CSC as energy and protein sources respectively (Table 1). Fresh cassava was purchased directly from farmers in villages in Morogoro rural district while and FW were obtained from the numerous fish processing factories around Mwanza city on the shores of Lake Victoria. The unpeeled roots were washed with clean water, chopped by hand into small slices and sun dried for three days to reduce HCN from 863 to 90.5 mg/kg DM (Bui Van Chinh and Le Viet Ly, (2001). It was then packed, weighed and stored under moisture free conditions. Hominy meal, cotton seed cake and minerals were purchased from feed stores in Morogoro town.

The treatment rations were: TR₁ (hay, CSC and HM), TR₂ (hay, CSC and CRM), TR₃ (hay, FW and HM) and TR₄ (hay, FW and CRM). The rations were balanced for energy, protein and other nutrients before being fed to the heifers. The experiment was run for a total of 81 days including a 21-day preliminary period to acclimatize the animals to the treatments and 60 days of data collection. The rations were offered separately and in equal amounts

Table 1: Ingredient composition of treatment rations (kg DM).

Ingredients	Treatments			
	TR ₁	TR ₂	TR ₃	TR ₄
Cotton seed cake (CSC)	315	480	-	-
Fish wastes (FW)	-	-	305	465
Hominy meal (HM)	665	-	675	-
Cassava root meal (CRM)	-	500	-	515
Minerals	20	20	20	20
Total	1000	1000	1000	1000

in the morning (0800 h) and afternoon (1500 h) at the rate of 11.6-g/kg-body weight. Hay and water were fed free choice.

Chemical analysis. Chemical content of the feed ingredients, treatment rations and hay were determined according to the A.O.A.C. (1990) methods. Sun dried FW samples were collected in the dry and wet seasons to establish if there were any seasonal differences in their chemical content.

Samples were fractionated into dry matter (DM) Ash, and crude fibre (CF) and crude protein. Crude protein was determined using a semi-automatic Kjeldatech method (N x 6.25) and ether extract (EE) the soxhlet extraction technique. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the method of Van Soest (1991). Minerals were analyzed by atomic absorption spectroscopy (AAS) using AAS UNICUM spectrophotometer model 919 and were read at wavelengths of 422.5 for Ca, 884 for P and 285 for Mg. Na and K were determined using the flame photometer technique.

Dry matter and body weight measurements. The dry matter intakes (DMI) were recorded daily and adjusted fortnightly to accommodate changes in bodyweight and then averaged for each heifer at the end of the experiment. Initial and final weights were recorded using a weighbridge for three consecutive days before and at the end of the experiment and at an interval of 14 days in between at 0600 h – 0700 before the morning

feed. The data was summarized at the end of the experiment and the average daily gain (ADG) calculated for each heifer.

Blood parameters. Blood samples were collected weekly from all the animals and analyzed for plasma Ca, P, glucose and protein. Samples for glucose analysis were collected into vacutainer tubes containing sodium fluoride (sodium fluoride acted both as an anticoagulant and as a preservative for glucose). The samples were centrifuged at 2000 rpm for 10 minutes and the clear plasma siphoned into labeled tubes, then frozen at -15 °C-20 °C to avoid glycolysis (Kaneko, (1989).

Blood samples for total protein; phosphorus and calcium determinations were collected in heparin containing vacutainer tubes and handled in a similar manner as those for glucose. Analysis for Ca and P were done using a spectrophotometer (model Cecil C 2041 2000, Cecil instruments Limited, UK). Total plasma protein was determined using RANDOX reagent kit from Randox laboratories, UK (1991). Plasma glucose was determined using RANDOX reagent kit from Randox laboratories, UK (1995) and read at wavelengths of 574 nm for Ca, 420 nm for P, 540 nm for total proteins and 540 nm for glucose.

Statistical Analysis. All the data collected were analyzed using the General Linear Model Procedure (GLMP) and means were compared using the LSD method (SAS, 1990).

Results

Chemical composition. The chemical composition of the supplement feeds and hay are presented in Table 2. Fish wastes collected during dry season had higher EE, DM and mineral contents than that those collected during the rainy season. Both FW had higher nutritive value than CSC. Hominy meal was superior to CRM in EE, CP and CF. Hay contained the lowest CP and high amounts of NDF and ADF.

The chemical compositions of the treatment rations are also summarized in Table 2. Average DM content of the treatment rations was above 960g/kg DM and the CP ranged from 201-206 g/kg DM in TR₁ to TR₄ respectively. Crude fat (EE) was highest in TR₃ (94 g/kg DM) and lowest in TR₂ (26 g/kg DM) and the ash content was highest in TR₄ (240 g/kg DM) and lowest in TR₁ (69 g/kg DM). Energy content was highest in rations containing CSC (TR₁ and TR₂) and lowest in rations containing FW (TR₃ and TR₄). The latter also had higher Ca and P contents than TR₁ and TR₂.

Growth performance There were no differences ($P>0.05$) in live weight gain between treatments (Table 3). The average daily gain (ADG) between rations was highest ($P<0.05$) in animals on TR₂ (620 g/day) and lowest in those on TR₄ (410 g/day). Differences ($P<0.05$) were also observed between treatment rations in terms of feed conversion efficiency (FCE) with TR₂ having the highest (0.116 g/kg) and TR₄ the lowest (0.085 g/kg). The combination of CRM and CSC showed higher ($P<0.05$) FCE than when CSC was fed in combination with HM or FW combined with both energy sources.

Total DMI. LS means for DMI in Table 3 show significant differences ($P<0.05$) between rations with animals on TR₂ having higher values followed by TR₁, TR₃, and TR₄ with average intakes of 5.47, 5.11, 4.98 and 4.89 kg/day respectively. Source of protein or energy supplement had effect ($P<0.05$) on DMI. Heifers on FW containing rations had lower ($P<0.05$) DMI than those on CSC. Cassava root meal in combination with CSC gave higher DMI ($P<0.05$) than when it was combined with FW.

Table 2: Chemical composition of experimental feeds and of treatment rations (g/kg DM).

Feed type	DM	CP	EE	Ash	CF	NDF	ADF	ME	(MJ/ kgDM)
Fish wastes									
Rainy season FW (SD)	961	396	151	347					
Dry seasons FW (SD)	985	397	218	344					
Cassava root meal									
Whole CRM	921	43	8	51					
Other experimental feeds									
Cotton seed cake	958	373	75	63		51		347	
Hominy meal	964	139	85	46		630		80	
Hay (<i>Brachiaria brizantha</i>) *	967	42	5	89		794		554	
TR ₁	969	201	76	69	113	449			13
TR ₂	967	202	26	74	116	426			12
TR ₃	973	203	94	167	51	470			11
TR ₄	972	206	58	240	63	601			9

DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = crude fiber,
SD =sun dried NDF = Neutral detergent fiber, ADF = Acid detergent fiber,
ME = Metabolizable energy.

Blood parameters. There were differences ($P<0.05$) between treatments in all the blood parameters. Total plasma proteins of animals on TR₂ (97.1g/l) were higher ($P<0.05$) than those on TR₄ (95g/l), TR₃ (92.3 g/l) and TR₁ (90.5 g/l) (Table 4). Rations with CRM (TR₂ and TR₄) had higher ($P<0.05$) plasma blood protein levels than those on HM (TR₁ and TR₃).

Maximum and minimum levels of Ca in the blood were highest in animals on ration TR₃ and were different ($P<0.05$) between rations (Table 4). Animals on rations containing FW had higher ($P<0.05$) levels of P than those with CSC (TR₁ vs TR₂) and the average P concentrations were 1.6mmol/l, 1.38mmol/l, 1.26mmol/l and 1.21mmol/l in animals on rations TR₄, TR₃, TR₂ and TR₁ respectively.

Plasma glucose was different ($P<0.05$) between treatment rations with the overall concentrations being 3.15mmol/l, 3.3mmol/l, 3.14mmol/l and 3.0mmol/l for TR₁, TR₂, TR₃ and TR₄ respectively (Table 4).

Discussion

The CP, NDF and ADF values for hay were within the range commonly reported for poor quality tropical forages (Göhl, 1981; Adepise and Oyedipe, 1985; Mtengeti, 1995). The CP for FW was lower than that reported by Ngate, (1997) and Mbamba, (2000), whereas the P value was higher. This is because the FW in Ngate's (1997) study included a significant proportion of whole fish and Mbamba (2000) worked on offal from marine fish. By-products

Table 3: The LS (means $\pm$ SEM) of live weight changes (LWC) (kg) of dairy heifers fed on different treatment ratios.

Weeks	Treatments				SEM	Pr > F	SIG.
	TR ₁	Tr ₂	TR ₃	TR ₄			
DMI (g/kg)	5.11 ^b	5.47 ^a	4.98 ^b	4.89 ^c	0.029	0.0001	***
LWC (kg)	29 ^a	32	29	26	1.408	0.0856	NS
ADG (g/d)	500 ^b	620 ^a	460 ^b	410 ^c	0.005	0.0001	***
FCE (g/kg)	0.097 ^b	0.116 ^a	0.092 ^b	0.085 ^c	0.025	0.0004	***

NS = Not significant

* = Significant at $P < 0.05$

*** = Highly significant at $P < 0.0001$

Super script ^{a, b, c;} means within each row bearing same letter are not significantly different at $P<0.05$.

Table 4: LS (means $\pm$ SEM) for the effect of treatment rations on different blood parameters.

Treatment	Protein (g/l),	Glucose (mmol/l)	Ca (mmol/l)	P (mmol/l)
TR ₁	90.5 ^c	3.15 ^b	2.28 ^c	1.21 ^c
TR ₂	97.1 ^a	3.30 ^a	2.36 ^{ab}	1.26 ^c
TR ₃	92.3 ^{bc}	3.14 ^b	2.40 ^a	1.38 ^b
TR ₄	95.0 ^{ab}	3.0 ^c	2.34 ^b	1.60 ^a
SEM	0.989	0.165	0.018	0.046
Pr>F	0.0001	0.0001	0.0001	0.0001
Significance	***	***	***	***

NS = Not significant

*** = Highly significant at $P < 0.0001$

Super script ^{a, b, c;} means within each column bearing same letter are not significantly different at $P<0.05$.

from Nile perch FW usually contain less flesh and more skeletal tissues (Hussein and Jordan, 1991a; Kjos, 2001). The CP value and P values noted could have been increased or decreased by the inclusion of N and minerals from the keratinous material and tissues e.g. scales and skin as no partitioning of the various carcass components was done after filleting. Johnson and Savage (1987) and Kjos (2001) reported several reasons for variation observed in the quality of FM/FW. According to the latter author, fish meals made from fish scraps contains higher ash and lower protein than meals made from whole fish.

The chemical contents of CSC and hominy meal were within the range reported by Thomke and Macha, (1986) and by Lekule *et al.* (1988). Cassava root meal in this experiment had higher values of CP, ash and crude fibre than those reported by Lekule *et al.* (1988). These differences could be attributed to variations in soil type, variety, stage of maturity at harvesting and the processing method used (Wanapat, 1999). Peels from the bitter varieties are also known to contain the N containing HCN (Lekule, 1990; Nguyen, 1996). They therefore have no much feeding unless cassava is dry processed (Nguyen, 1996; Bui Van Chinh and Le Viet Ly, 2001) to get rid of HCN.

The energy and protein content and the consumption of the treatment rations were within the range recommended for growing heifers (Singh *et al.*, 1991; ARC, 1990; McDowell (1992). The minimum total DMI in the present study was 4.89 kg/day and was within the recommended range for growing heifers weighing 150-200 kg and gaining 0.5 kg/day of 4.2 to 5.6 kg/head/day (Kearl, 1982). Studies with heifers in the same weight band (150 to 200 kg) and fed on different diets containing FW or CSC had DMI ranging from 2.6 to 4.6 kg/head/day (Rocha *et al.*, 1995). There seem to be synergistic interaction between CRM and CSC, which may explain the high DMI intake observed for TR₂. Cassava root meal has been reported to increase DMI in dairy cattle when included at 15 % of the diet DM (Silvester *et al.*, 1977;

Zinn and DePeter, 1991). Therdchai and Mikled (2001) substituted maize with CRM at the rate of 0, 50, 75 and 100 %, and reported total DMI of 4.49, 6.24, 5.85 and 5.83 kg/day respectively.

FW is an excellent source of ruminal undegradable protein (RUDP). Animals fed on low quality roughages while receiving a high proportion of RUDP may experience low DMI and high plasma total protein (Hussein and Jordan, 1991b, Veira *et al.* (1994)). This would suggest that CSC was only partially degraded in the rumen while most of the FW was RUDP (Pham Kim Cuong *et al.*, 2001). The superior performance of the animals on TR₂ was mostly due to the positive interaction between CSC and CRM, high DM degradation and higher ME content. Diet TR₄ on the other hand could not have effectively supported increased rumen organic matter digestion since some of the RUDP escaped intestinal digestion, absorption and passed out in faeces undigested.

Nocek and Polan (1984) reported increases in weight gain when CRM was included in ruminant diets. LuzMeyeles and Preston (1977) noted 30 % increase in weight in cattle fed CRM at 15 % of the DMI. Silvester *et al.* (1977) reported that cassava meal promotes higher gains because of its effects on improved intake. Heifers on all the rations showed a consistent weight increment of between 5 and 9 kg per fortnight. Animals receiving CRM and CSC showed superior weight gains than those on CRM and FW. This suggests an apparent synergistic interaction between CRM and the protein as earlier suggested. The high amylopectin content in cassava makes it a more suitable source of energy for ruminants than for monogastric animals (Kanjapaputhipong *et al.*, 2001) as cassava is an excellent source of fermentable carbohydrates. Starch in cassava tuber makes the synthesis of rumen microbial protein more efficient when it is the main dietary source of fermentable carbohydrate compared to other sugars (Rowe *et al.*, 1980).

Heifers receiving CRM and CSC also had superior daily weight gain than those fed on CRM and FW. Cassava root meal offered at

50, 75 and 100 % of the daily ration combined with low quality roughages (rice straw) has been shown to promote weight gain of 866, 779 and 695 g/day respectively (Therdchai and Milked, 2001). Zinn and DePeter. (1991), found that daily weight gain was significantly greater when 15 % of the diet DM consisted of CRM. The high energy in CRM improves efficient of gain and growth (Smith *et al.*, 1991; McDonald *et al.*, 1998). In this case, CSC provided slowly ruminal degradable protein (RDP), hence improving total rumen digestible organic matter availability (Pham Kim Cuong *et al.*, 2001). Such a scenario could provide more energy and higher rate of weight gain by the animals.

The normal range for blood plasma protein in grazing animals is 68-85g/l (Jain, 1986). This level increase in animals receiving high protein concentrates (Sawadogo *et al.*, 1991). Values in the present study were above the range for non-supplemented grazing animals. High total plasma protein noted in TR₃ and TR₄ suggests that FW was mostly digested in the lower gut after escaping ruminal breakdown. Veira *et al.* (1994) reported increased plasma albumin concentration when steers were fed with increasing levels of fishmeal. The significantly higher concentration of plasma protein in animals on TR₂ could be due to the sparing effect of the readily available energy from cassava. Hoover and Stokes (1991) have shown that when energy is readily available the animal is spared from using protein as an energy source, hence increasing the quantity mobilized into protein accretion. The amount of NH₃-N in the rumen could also have had an influence on the total protein concentration in the blood. Ruminal NH₃-N observed in this study was more than that required for microbial synthesis in the rumen. The excess ammonia could have been converted into body proteins (Singh *et al.*, 1991; Hoover and Stokes, 1991).

The use of FW in practical ruminant diets could provide opportunities for reducing costs of inorganic mineral supplements, particularly Ca and P (Mbamba, 2000). The observations made on the availability of the

two minerals when FW was included in the rations show the animals on TR₃ and TR₄ to have had significantly higher blood levels of Ca than those on TR₁. The high plasma Ca in TR₂ was not expected the animals on TR₃ and TR₄ received at least twice the recommended daily allowance for Ca. Judging from plasma levels; Ca appeared to be poorly available. However, as no attempt was made to assess urinary losses of Ca, it was not possible to quantify amount retained. The blood levels observed in this study suggest that FW could not provide adequate quantities of Ca as was expected, as cattle should have between 2.43 to 3.10 mmol/l of Ca (Kaneko, 1989). This level is however, known to be variable depending on many factors, e.g. age of the animals, physiological status and corresponding levels of P (McDowell, 1996).

Inorganic phosphate (P) is needed for the primary functions of growth, energy metabolism and reproduction (McDowell, 1992). The P levels observed in this study were lower than the recommended daily allowance (1.8 and 2.9 mmols/l) (Underwood and Suttle, 1999). Animals on TR₃ and TR₄ had levels approaching the recommended levels but were respectively 0.42 to 1.3 mmols/l below the recommended allowances regardless of the 30-46.5 % inclusion rate of FW. The amount of P in the rations showed that all animals received sufficient supply of P in the rations. The low plasma P levels would therefore, suggest poor uptake or low availability of P. The high oil and vitamin A content in FW might have interfered with Ca and P metabolism as high Vitamin A has been reported to negatively affect Vitamin D uptake and therefore P metabolism (McDowell, 1996; McDonald *et al.*, 1998).

The level of plasma glucose observed is indicative of energy supply at tissue level. Animals starved on rapidly available energy would normally show high levels of ketones i.e. Non-esterified Fatty Acids, triglycerides and Beta-hydroxybutyrate. Adequate glucose levels indicate that the animal received sufficient energy supply from the diet. Results in this experiment suggest that

animals in all the four treatment rations had glucose levels within the normal values for ruminants (Kaneko, 1989). Although CRM fed animals were expected to show high values of glucose (Aregheore, 1992), the inconsistency observed in this regard suggests that energy from CRM was best utilized when the diet contained CSC than FW.

Conclusions

Result of this study show that CRM can successfully replace HM as an energy source and that FW could replace CSC as a protein source and that the best results were obtainable where CRM was mixed with CSC. It is also concluded that CRM could be used alone as an energy source but that would require supplementation with protein rich feeds. As a protein supplement, FW can be successfully combined with energy at levels not exceeding 30 %. Recommended inclusion levels should be at 50 and 30 % for CRM and FW respectively.

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A new sweetpotato cultivar, “quick sweet” has an altered starch structure and low gelatinization temperature

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Abstract. “Quick Sweet” is a new cultivar released for fresh market use in Japan. It was derived from a cross between “Beniazuma” and “Kyushu 30.” The gelatinization temperature of “Quick Sweet” starch is about 20 °C lower than those of ordinary cultivars including its parents. Its starch granules show an abnormal morphology characterized by cracking into granules. Analyses of the chain-length distribution of amylopectin determined by high-performance anion-exchange chromatography (HPAEC) showed that “Quick Sweet” starch had a higher proportion of short chains (DP 6 - 11) compared to those in normal sweetpotato starch. The change in chain length distribution of amylopectin is thought to be the reason for the unique starch properties of “Quick Sweet”. Because of these starch properties, the storage roots can be cooked more quickly than ordinary cultivars. Eating quality of “Quick Sweet” after micro-waving is also good. Ordinary cultivars do not taste nice after micro-waving. It is thus expected to be a convenient cultivar for the busy Japanese.

Introduction

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is used as direct food, processed food, industrial starch, and animal feed in Japan. An investigation into the consumers’ preference and eating habits by the government showed that Japanese consumers’ preferences are guided by healthy issues and then convenience. This seems to be related to the

changes in work and life styles of Japanese who are so busy that they cannot spend much time cooking their own foods. To promote sweetpotato consumption and production in Japan, breeding must meet the concept of “convenience” as much as possible. Therefore, quick cooking ability is an important objective in Japanese breeding program. Starch properties may affect the cooking properties or taste of sweetpotato. However, it is known that variations in starch properties such as pasting properties and molecular structure of starch among sweetpotato varieties are rather small (Noda *et al.*, 1995; Katayama *et al.*, 1999). Sweetpotato breeding programs in Japan have been looking for genetic variations in starch properties. A breeding line, “Kanto No.116 (later released as “Quick Sweet”)” showed an abnormal morphology of starch granules. In this report, we describe the gelatinization and pasting properties, molecular structure of starch and cooking properties of this line and discuss a new breeding target in highly commercialized nations utilizing these starch properties.

Materials and Methods

Pedigree of “Quick Sweet”. The pedigree of “Quick Sweet” is shown in Figure 1. This cultivar was developed from a single cross of “Beniazuma” x “Kyushu No.30” at Ibusuki Branch of Kyushu National Agricultural Experiment Station in 1993.

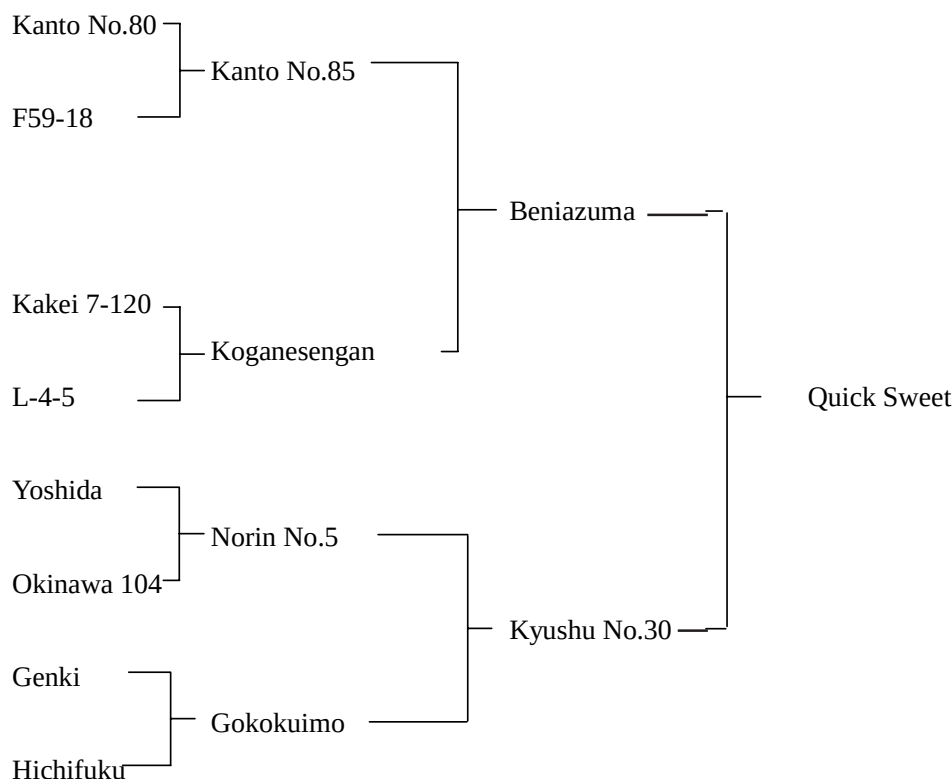


Figure 1: Pedigree of "Quick Sweet".

Plant materials and field experiments. The field experiments were carried out from 1998 to 2001 at the Yawara Upland Experimental Field of the NICS, Ibaraki in Japan. All plant materials were grown under standard sweetpotato cultivation practices. In brief, they were grown with vinyl mulching in a randomised block design with three replications. The materials were transplanted in late May and harvested in the middle of October. Harvested storage roots were stored at 15°C and 80% relative humidity for at least two weeks. Four to eight medium-sized storage roots per line were randomly selected for the extraction of starch. The storage roots were sliced, and the root tissues homogenized in water with a blender, and filtered through a 200-mesh sieve. The starch collected from the filtrate was washed with deionized water several times and then air-dried.

Starch Analytical Methods. The starch content, amylase content, starch pasting properties, gelatinization properties and chain-length distribution of amylopectin were analyzed as described by Katayama *et al.* (2002).

Cooking Experiments. To determine the time needed for cooking of the storage roots, tissue blocks (20mm x 15mm width) were subjected to steaming. They were taken out at 0, 3, 6, 9 and 12 minute intervals and homogenized in water (4 times volume of block). The homogenized were centrifuge and their brix values determined. In 2001, a panel of about 20 experts was used to determine the taste of the storage roots. The storage roots were subjected to two cooking methods: normal steaming for about one hour and microwave oven heating for about 10 minutes. After

tasting, their brix values were determined as above.

Results and Discussions

Yield performance of “Quick Sweet”. As shown in Table 1, “Quick Sweet” has similar yield performance as “Beniazuma” the most popular cultivar for table use in Japan. Although the dry matter content of “Quick Sweet” is slightly lower than that of “Beniazuma”, it still fits within the range of Japanese table cultivars. Storage root yield and dry matter content of this cultivar were lower than those of Japanese cultivars used for starch production.

Morphology of starch granules. Starch granules from “Quick Sweet” showed an abnormal morphology characterized by cracking into granules.

Gelatinization and pasting properties of “Quick Sweet” starch. Differential Scanning Calorimeter (DSC) analysis of 30% starch solutions showed that onset temperature, peak temperature and conclusion temperature of “Quick Sweet” starch were 39.0°C, 46.9°C, 64.8°C, respectively. These values were approximately 20°C lower than those of normal sweetpotato starches including the parents of “Quick Sweet”. Pasting temperatures of “Quick Sweet” starch determined by Rapid Visco Analyzer with 7% and 10% starch suspension were 51.4 - 52.6°C. These values were also approximately 20°C lower than those of normal sweetpotato starches. These starch

properties are quite unique and unknown among sweetpotato cultivars.

Amylose content of “Quick Sweet”. Amylase content of “Quick Sweet” starch was about 16 %. Since this value is similar to those of normal sweetpotato starches, it is unlikely that the unique starch properties of “Quick Sweet” are caused by shift of amylose content.

Chain-length distribution of amylopectin of “Quick Sweet” starch. Analyses of the chain-length distribution of amylopectin determined by high-performance anion-exchange chromatography (HPAEC) showed that “Quick Sweet” starch had a higher proportion of short chains (DP 6 - 11) and a lower proportion of chains between DP 12 - 28 than those in normal sweetpotato starch including the parents. Kitahara *et al.* (1999) reported the high proportion of short chains in amylopectins of two sweetpotato lines with low pasting temperatures of 61.5 and 66.5°C. Thus, the change in chain length distribution of amylopectin is thought to be the reason for the unique starch properties of “Quick Sweet”.

Cooking properties of “Quick Sweet”. When small blocks of storage roots (20mm x 15mm width) were subjected to steaming, the brix values of “Quick Sweet” blocks increased more rapidly than those of normal sweetpotato, “Beniazuma” and “Kokei No.14”. It rose to a plateau at 7% within 3 min. This suggests that “Quick Sweet” can be cooked more quickly by steaming

Table 1: Yield performance of “Quick Sweet”.

Cultivar	Quick Sweet	Beniazuma	Kokei No.14
Marketable root yield (t/ha)	28.6	26.7	26.7
Dry matter content (%)	34.3	35.5	31.2
Storage root shape	Spindle	Long spindle	Long spindle
Skin color	Purplish red	Deep purplish red	Purplish red
Flesh color	Light yellow	Yellow	Light yellow

Note: Values are the average of data from 1998 to 2000.

compared to other normal varieties. Tasting panel experiments showed that “Quick Sweet” was as sweet as “Beniazuma” after conventional steam cooking. The brix values of steamed “Quick Sweet” were about 7%. These values were similar to those of “Beniazuma”. The brix values of “Beniazuma” after microwave cooking were around 5% compared to “Quick Sweet” brix values of about 6.5%. “Quick Sweet” remained sweet enough even after microwave cooking. The sweetness of sweetpotato is derived from maltose, which is formed from pasted starch by β -amylase during cooking. It is likely that changes in cooking properties of “Quick Sweet” are derived from the shift of pasting properties of its starch.

We investigated the origin of the starch properties of “Quick Sweet”. All the progenitors of “Quick Sweet” have normal sweetpotato starch. Therefore, it is likely that recessive gene(s) controls this starch property and the parents have this gene(s) heterogeneously. Since similar shift in starch property was reported in some plants which had modified starch synthase II or III gene (Kossmann and Lloyd, 2000), we are investigating the genes coding starch synthase II and III of “Quick Sweet” to understand the genetic mechanism of its starch properties. It is expected that this

variety will meet the healthy requirements and fast cooking time cherished by the busy Japanese.

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Improvement and popularization of diversified cassava products for income generation and food security: A case study of *Kibabu*

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Abstract. *Kibabu* is a traditional plain deep fried cassava product prepared from cassava paste. It was noticed however that the product was deficient in nutrients and that there was also room to improve product acceptability. A study was conducted to improve nutrient content and palatability of traditional *kibabu*, using 80% cassava and other staple mixture and 20% onion-garlic inclusion in the formulation. Laboratory analysis and sensory evaluation were conducted on *kibabu* from each of the formulations. Results showed that use of groundnuts and soybeans improved the nutritive value while the incorporation of coconut improved palatability of *kibabu* significantly ($P < 0.05$). Plain cassava *kibabu* was poor in nutrients and rich in energy. Once blended with groundnuts or soybean, however, its nutrient content improved greatly. The dry matter of the formulated product ranged from 70.36 to 90.34%. On dry weight basis, the nutrient content was as follows: crude protein, 1.21-19.69; fat, 6.74-41.51% and ash content, 1.96-12.45%. The fibre content ranged from 5.46-25.85%, with coconut contributing most to this increase. The improvement resulting from blending with coconut was not outstanding except for fat and protein. Incorporation of high levels of soybean in the formulation increased the protein content greatly, but it also introduced the bean flavour that lowered the

acceptability of the resulting *kibabu*. Blending coconut, groundnuts and/or soybeans could result in a product that is acceptable in addition to being nutritionally balanced.

Introduction

Cassava is an important food crop for developing countries, being the main source of energy for between 200 and 300 million people (Gevaudan *et al.*, 1998). In Tanzania, cassava is an important subsistence food crop, although it is still considered by many people outside the production areas as a famine reserve crop when cereals, especially maize fail, due to its drought tolerance. Around 84% of total production in the country is utilized as human food. The remaining fraction is used for livestock feed, starch making and export (<http://www.globalstrategicforcassava.com/development/Africa/Tanzania.htm>, 2000). This crop is bulky and highly perishable. The biggest advantage of this crop is its availability all year round thus contributing to food security, and its high energy content (Hahn *et al.*, 1979) that helps in minimizing incidences of energy malnutrition. Due to its inherent characteristics, including having cyanide (Essers, 1995), the value of cassava could be improved through improved processing. Such improvement will increase the scope of utilization and commercialization, which will

in turn stimulate production. The Government of Tanzania has long been advised to encourage production and local consumption of cassava, organize the marketing of cassava and promote cassava drying and the milling industry for export (Silayo *et al.*, 2001). Exploitation of various processing methods is often regarded as a means to promote production and enhance food security and commercialization (Silayo *et al.*, 2001).

In Tanzania, processing of cassava for value adding has centred mainly on production of fermented and non-fermented flours for making porridge. Such flours could be blended with cereal flours to improve acceptability of the cassava-based porridges. Exact proportions of these blends have not been fully established. Cassava has also been used in baked products (e.g., bread) and fried products like doughnuts, buns and chapatti although not to the extent of the stiff porridges. Another area of utilization of cassava is in the starch industry for food and non-food uses. This product can be obtained from the fresh dried cassava. The easiest form of extraction of this cassava starch is from the fresh cassava using graters to crush the cassava into a fine paste.

Literature on use of cassava as a paste-based product is scanty. *Yake yake* is one paste product obtained after peeling, washing, grating, drying and sieving the cassava to obtain a meal that is moulded and steam-baked). *Agbeli kaklo* is a second product encountered in literature resembling *yake yake* but instead of steam-baking, the meal is mixed with meat, moulded into small cylinders and fried (Doku, 1969).

Only one traditional paste product (*kibabu*) from Muheza district that was encountered in a Participatory Rapid Appraisal (PRA) study in the mentioned district (Silayo *et al.*, 2001) could relate to the *yake yake* and *agbeli kaklo*. This product looked promising in broadening the food types of cassava of the Tanzanian community but needed improvement in processing quality and sensory attributes to improve its acceptability. It was prepared from onions and

salt as the only ingredients that were mixed with squeezed cassava paste prior to frying. The objective of this study was therefore to improve quality and acceptability of this product through studying chemical composition and sensory attributes for purposes of identifying acceptable formulations.

Materials and Methods

Source of raw materials. The raw materials used in this study included cassava (Kigoma variety), groundnuts, onions, garlic, red pepper and coconut. Soybean (Bossier variety) also purchased from the same market was also included in the study.

Preparation of raw materials. Cassava roots were peeled, split longitudinally, the mid rib was removed and the remaining cassava grated. After grating, the paste was squeezed in a polypropylene bag until no more extract came out. This paste was retained for formulation of *kibabu* that was done on the same day of squeezing. Then, groundnuts were sorted to remove stones, rotten groundnuts and any chaff. The nuts were roasted and skins removed by rubbing between the hands. Coconut was broken into two halves and using a coconut grater, the flesh was grated and then reserved for use during formulation. Soybean seeds were sorted as for groundnuts washed with water and then soaked in water (12h) with 6h changing of soaking water. The soaking water was drained and the soybeans were boiled in water (1:10 for 30 min. at 100°C). The seeds were then cooled with cold water followed by manual decortication. These were then dried in an oven at 70°C and the flour sieved using a 160µm sieve. The sieved flour was retained until required for formulation. The spices used were onions and garlic. Onions were peeled, washed, cut into very thin slices and retained in an airtight container until needed for formulation. Garlic tubers were likewise treated (Table 1).

Table 1: Formulations of *kibabu* using different ingredients.

Sample number	Amount of ingredient (g)			
	Cassava paste	Ingredient ¹	Onion	Garlic
<i>Groundnut-based kibabu</i>				
628	256	64	60	20
910	192	128	60	20
318	128	192	60	20
274	64	256	60	20
<i>Coconut-based kibabu</i>				
562	256	64	60	20
825	192	128	60	20
251	128	192	60	20
512	64	256	60	20
<i>Soybean-based kibabu</i>				
166	256	64	60	20
327	192	128	60	20
743	128	192	60	20
439	64	256	60	20
<i>Plain kibabu</i>				
256	320	0	60	20

¹ The ingredient is groundnut, coconut or soybean depending on formulation.

The general procedure for preparing the cassava-based *kibabu* is summarised in Figure 1. This simply involved moulding in the palm the formulated mixture into a cylindrical mould of dimension 2.5 cm diameter and 7 cm length. Then deep frying the mould for 8-10 minutes to a nice golden yellow colour. Each formulation was done in triplicate. The different formulations are presented in Table 1.

Chemical analysis of *kibabu* samples. The *kibabu* samples were subjected to chemical analysis to establish their proximate composition. The samples were analyzed for moisture content, ash, crude protein crude fat, ether extract, crude fibre and carbohydrate content (AOAC, 1995). These analyses were conducted in duplicates.

Sensory evaluation of *kibabu*. The *kibabu* samples from different formulations were subjected to sensory evaluation using a 5 point hedonic scale where 1-5 stood for dislike extremely, dislike moderately, neither like nor dislike, like moderately and like extremely, respectively. The data obtained was coded and subjected to statistical analysis using Statistical Package for Social Sciences (SPSS) programme.

Results and Discussion

Chemical composition. The proximate analysis of the different *kibabu* samples prepared in the laboratory, where the ratio of spices used was 3:1 onions:garlic is summarized in Table 2. The nutrient content was as follows: crude protein, 1.21-19.69; fat,

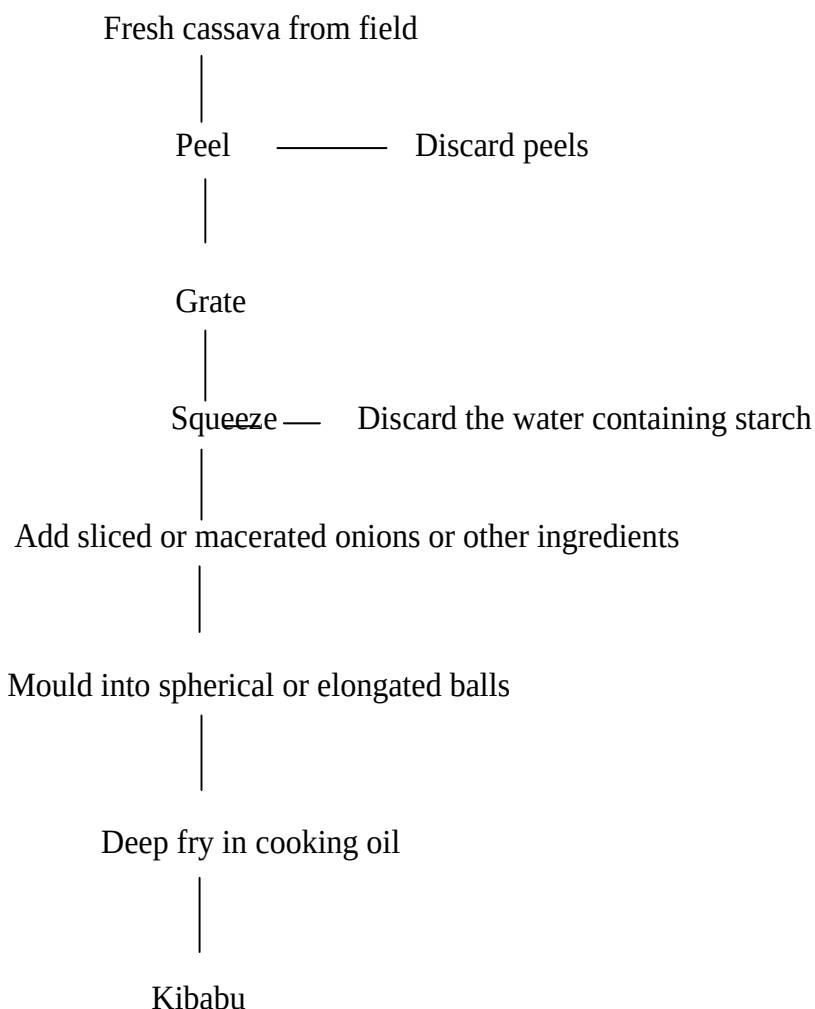


Figure 1: Flow diagram for production of cassava *kibabu*.

6.74-41.51% and ash content, 1.96-12.45%. The fibre content ranged from 5.46-25.85%, with coconut contributing most to this increase. The improvement resulting from blending with coconut was not outstanding except for fat, protein and palatability (Table 3).

As expected, plain cassava was shown to have the lowest fat and protein contents. Fibre content was also generally low, while the carbohydrate content was highest. Judging from these laboratory results, there was a limit to which soybean could be used in the blending. For example, as seen from Table 2 it

was not possible to increase soybean content above 40% of the cassava component. This was because the binding properties of the cassava would be marginalized and thus the resulting mixture could not bind properly during frying, consequently leading to fragmentation. Blending with groundnuts or soybean had marked improvement on the crude fibre. Generally, increasing the proportion of legume in the formulation increased the crude fibre, crude protein, and crude fat. However, the total carbohydrate content decreased following this increase. Soybean seemed to produce the highest

Table 2: Chemical composition of *kibabu* (dry weight basis).

Sample	Formulation ¹	Moisture (%)	Ash (%)	Crude fibre (%)	Crude protein (%)	Fat (%)	Carbohydrate (%)
Cassava:coconut							
256	5:0	27.01	2.37	5.46	1.21	6.74	57.22
562	4:1	25.01	2.73	18.36	2.31	21.24	30.36
825	3:2	27.32	2.34	21.70	2.96	25.28	10.40
251	2:3	22.86	2.57	25.05	3.91	37.05	8.57
512	1:4	11.26	1.96	25.85	5.62	36.49	28.82
Cassava:soybean							
166	4:1	29.64	2.78	11.00	11.63	13.51	31.44
327	3:2	19.96	2.53	15.50	18.10	33.24	10.68
Cassava:groundnut							
627	4:1	21.45	12.45	2.85	9.10	12.36	41.79
910	3:2	18.35	9.36	9.17	11.72	30.99	10.92
318	2:3	15.16	3.59	20.16	16.10	38.99	6.01
274	1:4	9.61	2.96	20.69	19.69	41.51	5.54

¹ Formulations missing in the cassava:soybean combinations failed to produce *kibabu*.

Table 3: Mean scores of sensory evaluation results for different formulations of *Kibabu*.

Sample ¹	Taste	Texture	Smell	Colour	Appearance	General acceptability
256 (Cassava)	2.57b	2.60b	3.77a	3.27a	3.67a	2.87a
562(Cas::Co)	2.70b	3.00a	2.93b	3.43a	3.20a	3.17a
825 (Cas:Co)	2.90b	3.20a	2.83b	3.40a	3.50a	3.27a
251 (Cas::Co)	3.27a	2.90a	3.37a	3.70a	3.60a	3.27a
512(Cas:Co)	3.23a	3.23a	3.17a	3.77a	3.57a	3.30a
166 (Cas:Soy)	1.80d	2.37c	3.07b	3.30a	3.07a	1.40c
327 (Cas:Soy)	2.03c	2.60b	2.43c	3.33a	3.77a	2.47b
629(Cas:Gnut)	2.60b	2.77a	2.57c	3.53a	3.50a	2.63b
910(Cas:Gnut)	3.27a	2.83a	3.57a	3.40a	3.10b	3.03a
318(Cas:Gnut)	3.30a	3.07a	3.00a	3.00b	2.83b	2.90a
274(Cas:Gnut)	3.63a	2.83a	3.53a	3.13a	2.73c	3.37a
Grand mean	2.83	2.86	2.89	3.40	3.32	2.92

¹ Cas=Cassava, Co=Coconut, Soy=Soybean and Gnut=Groundnut. The ratios are as shown in Table 1.

² Values in the same column bearing a different superscripts are significantly different at (P<0.05).

content of protein due to the fact that the protein content of soybean is almost twice that of groundnut. The fat content was highest in coconut formulations and increased as the amount of coconut was increased. This was due to the fact that coconut flesh is quite fibrous.

Sensory evaluation. The sensory evaluation results are summarized in Table 3. For *kibabu* to be considered acceptable the mean score should be at least 3 for a particular parameter. General acceptability encompasses all the parameters and is treated as a true reflection of what the panelist will consider after taking into account all the parameters determining acceptability. Looking at the results, blending cassava with coconuts was the most acceptable.

Implications

Results of this study showed a possibility of producing acceptable *kibabu* by blending with other food staples that could supply the nutrients lacking in cassava. Such staples include coconut that could improve significantly the fat content and soybean and groundnut that could improve in addition to the fat, the protein status. Whereas despite biggest nutrient content improvement shown by soybean, acceptability could pose a serious challenge. Groundnut used in the grounded form offer promising potential. Disregarding the nutritional inferiority of coconut, acceptability results seemed quite acceptable for all formulations used in the study, although the means were not significantly different from that of plain cassava *kibabu*. This hints to the potential of using coconut to blend with cassava paste to produce acceptable snacks. Alternatively, coconut could be used to blend the soybean and groundnut blended *kibabu* to improve acceptability while maintaining acceptable nutritional status.

Acknowledgements

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Cassava in Tanzania: A famine or commercial reserve?

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Abstract. Tanzania is one of the largest cassava producers in Africa. About 655,700 ha of land are under cassava with a total annual production of about 1,795,400 tons. Cassava is a staple food crop in most of the semi-arid and the frequently drought stricken areas. For this reason cassava has traditionally been considered a famine reserve crop. The main objective of this paper is to provide evidence that there is an opportunity to change the role of cassava in most farming systems in Tanzania. That cassava is becoming an important source of income (a cash reserve). The paper is based on case studies undertaken in selected villages in Tanzania. The results show that cassava producers/processors can earn as much as Tanzanian shillings 170,000 per month from cassava. This amount is more than three times the minimum wage in Tanzania.

Introduction

Tanzania's agricultural sector. Agriculture has always been considered the backbone of the Tanzanian economy. This is mainly because it contributes a large share of the national output. Lately, it has been estimated that agriculture contributes on average about 50% of Tanzania GDP. Agriculture is also the main foreign exchange earner of the country; the share of the agricultural exports in total exports is estimated at about 56%. Agriculture is also rated as the main employer of the rural population. According to the household budget survey (NBS 2002) 74% and 26% of rural and urban population respectively are engaged in agricultural related activities.

The agricultural sector in Tanzania has been estimated to grow at an average rate of about 3.5% between 1990 and 2001. According to World Bank (2000) export crops (including coffee, cotton, cashewnuts, tobacco and tea) contribute about 9% of the value of agricultural output. Food crops (mainly maize, rice, wheat, sorghum/millet, cassava and beans) account for about 74%. Of this, cassava contributes about 4.5 % (Figure 1). Despite the high contribution of food crops to agricultural output the production growth rate of the food crops has been relatively lower than that of cash crops for example between 1987 and 2001 the six main food crops grew at 3.5% per year while export crops grew at 5.4% per year (Lazaro and Mdoe, 2003). This could partly be due to underestimation of data for food crops but also because the growth of food crops is generally limited by the demand constraint. Food crops are basically limited to the domestic market.

An overview of cassava. Cassava, scientifically known as *Manihot esculenta* Crantz was introduced in Africa in the 16th century by early European traders (FAO, 2000). Cassava is a special crop because of its adaptability to a wide range of ecological and agronomic conditions. Cassava is produced widely in Asia, Latin America and Sub-Saharan Africa as a source of food and cash. Cassava production in Africa increased at a rate of 2.4% per year from 1973-75 to 1983-85 and 4.2 % from 1983-85 to 1993-95 (FAO 2000). Production during 1993-95 was estimated at 83,062,000 tonnes. Major cassava producing countries in Africa include Nigeria,

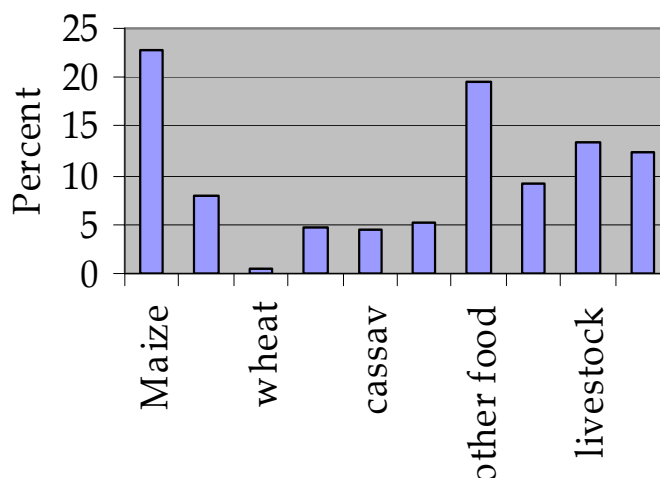


Figure 1: Contribution of cassava to Agricultural Output.

Democratic Republic of Congo and Tanzania. The average annual production of cassava in Tanzania during the 1992-1999 periods was about 1,640 million tonnes (URT, 2000). Major cassava producing regions include Mtwara, Mara and Ruvuma regions. These regions cultivated about 12.2%, 11.7% and 11.3% of total cassava planted area respectively during the 1998/99 season. Large cassava planted areas are also found in Mwanza (8.3%), Kigoma (6.5), Lindi (6.1%), Coast (6.4%), Shinyanga (5.9%), and Kagera (5.9%). The remaining 25.7% planted cassava area is spread in other regions (URT 2001).

Cassava is generally grown on soils with poor fertility, in semi-arid type of climate that is frequently drought stricken. Cassava is known for its ability to do well in poor soils where other field crops can not be grown without substantial input supplementation. Cassava has therefore played a very important role in ensuring food security in most perpetually drought stricken areas. For this reason cassava in Tanzania has often been categorized as a 'famine reserve' crop. This implies that the main objective for cassava production is to serve as a coping strategy against incidences of famine. Cassava farms have in general remained small. During the agricultural survey of 1998/99 about 51% of

sampled households cultivating cassava, cultivated between 2 to 5 ha (NBS, 2001).

The majority of cassava producers use traditional production methods. Hand hoes are the main tools used for land preparation, planting, weeding and harvesting. In processing, the main tool used is a knife, although processing machines (manual and powered) have recently been introduced in cassava producing areas. Both men and women are involved in cassava processing but women dominate in the processing. Recent studies conducted in selected regions in Tanzania show that cassava is increasingly becoming an important cash crop. To assess the importance of cassava in Tanzania this paper analyses data from case studies and secondary data from the Ministry of Agriculture. The main objective of this paper is to present evidence of change of the role of cassava in Tanzania from a famine reserve to a cash crop. Cassava is becoming a commercial reserve because of its increased importance as a cash crop.

Methodology

This paper is based on secondary data obtained from the Ministry of Agriculture and Food Security (MAFS) publications in

Tanzania, and The Food and Agriculture Organization of the United Nations (FAO). Primary data from case studies is used to complement secondary data. Case studies conducted in Dar-Es-salaam, Coast and Dodoma regions are used (Lisasi, 2003; Assenga, 2003).

Results and Discussion

Cassava output. Cassava is the most important root crop in Tanzania. According to the 1998/99 agricultural survey (NBS, 2001) total planted area in the sampled households was estimated at 848,126 ha during the 1998/99 season. This made up about 73% of total area under roots and tuber crops (Table 1). Other roots and tuber crops cultivated included sweetpotatoes (23%), irish potatoes (3%), yams and cocoyams (1%).

The survey results also showed that about 21% of total sampled households cultivated cassava and 15% of cultivated area by sampled households was planted with cassava (Table 1). Based on this data cassava is second to maize in terms of the proportion of households cultivating cassava and area under the crop.

Cassava is largely cultivated intercropped with other crops and in some cases in rotation with other crops. Important crop mixtures include:

1. Cassava with maize or cassava with sorghum: this mixture is important in almost all dry areas of Tanzania (e.g Dodoma, Singida, Mwanza, Mara, Tabora, Shinyanga and dry areas of Iringa).
2. Coconut with cassava that is cassava (sometimes mixed with maize) is planted in the coconut field interspaces. This is very common in coastal areas (Mtwara, Lindi, Coast, and Tanga regions).

This cropping system and the fact that cassava is largely harvested piece-meal makes estimation of cassava production very difficult. For this reason there is often a large discrepancy on cassava data from different sources and therefore such data should always be interpreted with caution. The annual cassava production is about 1,600 million tonnes (URT, 2000, URT 1998). The trend in cassava production is shown in Figure 2. The figure shows that cassava production has been increasing from 1960s to early 1990s when production started to decline during 1992-94. One of the reasons for the decline was lack of market for cassava. During the 1980s the National Milling Cooperation (NMC) and regional and district cooperative societies were buying dried cassava from farmers. NMC was established in 1967 as one of the state owned institution

Table 1: Proportion of households cultivating and planted area of food crops.

Crop	Number of holdings	%	Planted area	%
Maize	3,233,640	40	3,010,631.08	55
Paddy	685,257	8	503,532.56	9
Sorghum	866,975	11	551,707.5	10
Bulrush millet	207,671	3	165,918.69	3
Finger millet	192,287	2	90,881.82	1.6
Wheat	60,896	0.8	35,811.92	0.6
Cassava	1,697,321	21	848,125.9	15
Sweet potato	1,017,012	12.6	266,883.58	5
Irish Potatoes	76,427	0.9	28,420.74	0.5
Yam and cocoyam	64,073	0.8	11,437.04	0.2
Total	8,101,559	100	5,513,350.3	100

Source: URT (2001).

that had a legal monopoly of buying and selling food grains including cassava as well as to import and export food (Ashimogo, 1995). Figure 3 shows dried cassava purchases by NMC, the purchases were declining until 1990 where no cassava was purchased. This was mainly because in July 1988 NMC like other state owned institutions, lost its food crops buying monopoly and was not obliged to buy food crops (Turuka, 1995). During 1990/91 NMC ceased to be a major food-marketing agent as credit restriction reduced official purchases (Ashimogo, 1995). Despite the inefficiencies of NMC it ensured a ready market for cassava. This market assurance acted as a stimulus to cassava production and processing.

The lack of reliable market is partly a factor that limits the potential for cassava production in Tanzania. Following the liberalization of markets for agricultural products in 1980s marketing of cassava like other agricultural products was left in the hands of private traders. This change has negatively affected the marketing of dried cassava. The majority of private traders are more involved in trading high value cereals such as maize and rice. The few who are still interested in cassava confine their activities to more accessible areas. The few traders who operate in less accessible areas normally face little or no competition and hence offer low prices, resulting into low returns from cassava.

Figure 2: Dried cassava production and use 1964-1996

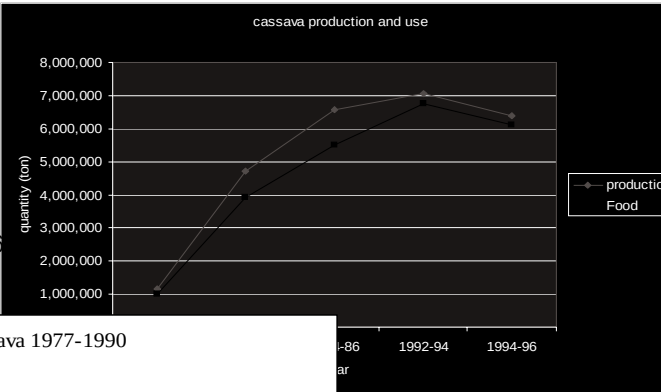


Figure 3: Trends in cassava purchases by NMC (Source URT 1992).

The market prospects for cassava will therefore depend on adding value to cassava through processing and utilization.

Cassava processing and utilization. Domestic use of cassava is largely limited to food (Figure 2). Both cassava roots and leaves are consumed. Roots are rich in carbohydrates while leaves are rich in proteins and minerals. Data on use of cassava leaves is however not documented thus this section will focus more on cassava roots. About 96% of cassava produced during 1992-94 and 1994-96 was used for food. Whereas between 1979-81 and 1984-86 the proportion of cassava that was used for food was 83% and 84% respectively. The trend in the per capita consumption of cassava is indicated in Figure 4. The figure shows that there was a decline in consumption during the period 1992-94. At this time production started to decline. The decline of per capita cassava consumption can as well be explained by the fact that in 1990 NMC the sole buyer and seller of dry cassava was dissolved. This limited the amount of cassava marketed and therefore reduced dramatically the consumption of cassava.

During the 1960s up to late 1980s some cassava was exported by NMC, and it made up about 52% of total quantity of food crops exported by NMC. NMC stopped exporting

cassava during 1987/88. Even then the export level for cassava was very low. The low volume of cassava export and alternative uses such as feed have limited the potential for cassava as a commercial crop in Tanzania. Empirical evidence has shown that cassava producers in Tanzania could increase cassava production if alternative uses of cassava are introduced (Shem *et al.*, 2003). The data showed that area under cassava production in two villages in the Coast region more than doubled (from 168.5 acres to 375.5 acres) between 2000 and 2003 after introducing the processing of cassava-based feed in the region

The utilization of cassava roots is sometimes limited by the toxicity of some cassava varieties. The toxic substance-cyanide contained in some cassava varieties is harmful to humans. The consumption of these varieties requires processing to reduce the levels of toxic cyanide to non-toxic levels. There are many cassava-processing procedures. Broadly it involves cutting the roots (peeled or unpeeled) into smaller pieces and drying (with or without fermentation). Three reasons that make cassava processing critical are: i) to reduce or remove the toxicity ii) to minimise losses from its perishability and iii) to reduce its bulkiness. Cassava processing therefore increases the value of cassava. A

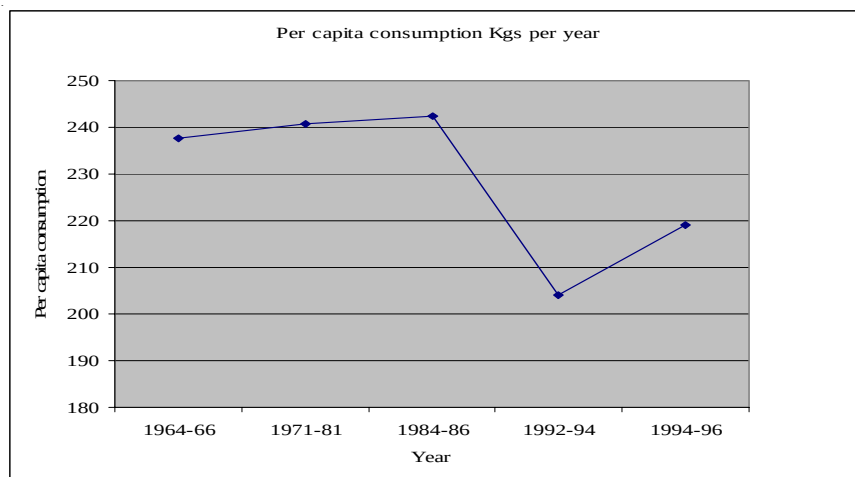


Figure 4: Per capita consumption of cassava.

case study conducted in the Coast region showed that the value of cassava in a domestic market increased by 32% compared to the value of an equivalent quantity of fresh cassava (TARPII-SUA, 2002). According to Nweke *et al.* (1998) about 75% of total cassava produced in Tanzania is processed while only 25% is used fresh. Cassava processing is largely done at household level where small quantities are processed for consumption and for sell in local markets. Introduction of simple cassava processing machines (chippers and graters) has been reported to increase levels of cassava processing (Mutayoba *et al.*, 2003). Industrial cassava processing in Tanzania is very limited. A cassava starch-processing factory was established in the lake zone cassava producing area but is not operational partly because of the limited supply of raw cassava.

Cassava commercialisation. For the majority of the rural population, agriculture is the main source of income. They generate income through sales of crops and/or livestock and livestock products. Data presented earlier shows that cassava in Tanzania is largely used for food. However, it is argued in this paper that cassava has a high potential to be a commercial crop or a source of income. Cassava generally competes with the traditional cereal crops. However, studies have shown that one of the main cassava advantages over cereal production is its low cost of production. A case study in the Coast region of Tanzania showed that the cost of production of cassava was about 62% less than that for paddy. For this reason although the market price for paddy is higher than that for cassava the returns to cassava production are generally higher than that for rice. Data from the coast region showed that the returns to cassava production were 22% higher than that for rice (TARP II-SUA, 2002).

A case study conducted in Dar-es-Salaam showed that cassava traders earned as high as TAS 170,000 per month on selling cassava flour in the local markets. In Dodoma region, cassava processors earned as high as TAS

59,000 per month. These case studies show that there is potential for commercialization of cassava

Governments efforts to promote cassava.

Realizing the importance of cassava the government of Tanzania through the National Agricultural Research System and other institutions such as Universities has made efforts to promote the crop. These efforts include investments in research, and establishment of policy guidelines for cassava production. Cassava research for a long time concentrated on developing better yielding varieties, agronomic practices and control of major pests of cassava. These research activities have often been done in collaboration with international organizations. The main objective therefore was to increase production levels and productivity. Research results show that improved varieties yield upto 25 tonnes per hectare (TARP II-SUA, 2002). The use of such improved varieties resulted into increased net returns to cassava production. It has been estimated that with improved varieties net returns from sell of fresh cassava range between TAS 220,000 and 340,000 per ha compared to traditional varieties that range between 160,000 and 310,000 (TARP II-SUA, 2002). Together with these efforts more research efforts have been recently directed to cassava processing and utilization (Lekule *et al.*, 2002). This include introduction of processing equipment and alternatives to cassava utilization (Silayo, 2003).

Together with research efforts the government made efforts on policy issues. According to the agricultural and livestock policy of 1997(URT, 1997), cassava was identified as one of the crops categorized as non-traditional export crops. However, the export market for cassava is not increasing. It, therefore, requires more efforts to improve the export market of cassava for Tanzania. At regional level, there are efforts as well to improve cassava production. For example in the semi-arid central region of Dodoma cassava was traditionally promoted as a

famine reserve crop. However realizing that cassava plays a bigger role in the region, the local government by-law of 1994 was amended in 2000 and re-categorized cassava as a 'food crop' rather than a 'famine reserve crop' (Lazaro *et al.*, 2003). There have also been government campaigns to promote cassava for food security. These government efforts have been instrument in promoting cassava production in Tanzania.

Implications

The analysis presented in this paper show that there is potential for cassava to be a commercial crop for Tanzania rather than just a famine reserve. There is potential for marketing cassava both domestically and abroad. Evidence has shown that with assurance of a reliable market, cassava production can be increased. It is suggested here that the exploitation of this potential depends largely on improvements in processing of cassava into more products with alternative uses.

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Nutritive value of fresh cassava tubers, cassava root meal and cassava chips for growing - finishing pigs

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Abstract. Three experiments were carried out to evaluate the nutritive value of fresh unpeeled cassava tubers, peeled, soaked cassava tubers, cassava root meal and cassava chips as energy sources for growing-finishing pigs. The varieties used were sweet and bitter types. The initial weight of the pigs ranged from 12 to 38 kg and were slaughtered when they made 90 kg. Their feed intake, growth rate and carcass characteristics were determined. The digestibility trial involved 4 castrated males in a 4x4 Latin square design. Performance of pigs was comparable to pigs fed other energy sources (or commercial cereal based diet). Pig growth rate ranged from 478 to 660 g/pig /day. Digestibility and feed efficiency of cassava-based diets were high, although young pigs (below 20 kg) tended to develop gastro-intestinal disturbances and parakeratosis when fed fresh cassava. The carcass quality was slightly affected. Carcasses from pigs fed on cassava diets were leaner and heavier than those on other rations. The studies concluded that varieties of sweet cassava could be fed fresh to pigs either peeled or unpeeled or in form of cassava chips. Further, fresh cassava can be soaked in water for one day whereas cassava chips can be dried for 8 to 10 hours prior to feeding to reduce HCN levels. Cassava can constitute the only energy source in diets of pigs provided that such diets are well balanced for protein, minerals and vitamins. The use of cassava in livestock feeds will promote cassava production and provide a sustainable outlet for this underutilised but highly adaptable crop.

Introduction

The currently fast expanding global human population suggests that large proportion of meat will come from pigs and poultry for they are very prolific, have a high, growth rate, feed efficiency and short generation interval compared to ruminants. Moreover, the pig serves as a source of cooking fat (lard), biogas, manure and bristles/leather. Consequently, pig production is fast rising in many countries including Tanzania. However, there are constraints to pig production in Tanzania. Among these is the nutritional deficiency particularly energy and protein. These contribute to the low productivity of pigs. This is usually a result of competition for feed stuff with humans and other livestock. The supply of essential nutrients from commercial sources is becoming expensive. Milling by-products, which are the main feed sources for pigs, are relatively expensive and not accessible in many parts of the country. Feed costs account for about 70-80% of costs of raising pigs (Henry and Correa, 2003). So the majority of smallholder farmers feed their pigs on grass, brewery wastes and human food leftovers. Efficiency and economy of production can greatly be improved by use of fairly-balanced rations based on cheap and abundant energy source.

Recently, cassava has been found to be a cheap source of energy capable of replacing up to 50% of expensive cereals like maize, sorghum and wheat. Moreover, its starch is highly digestible (Balagopal, *et al.*, 1997). Cassava is resistant to drought, diseases, and

pests and has no critical time of planting, thus is very suitable for low-income smallholder farmers. Nevertheless, it is deficient in proteins and vitamins, thus it must be supplemented with other source of feeds rich in these ingredients (Liliana, 1995; FAO and IFAD, 2000). The cyanogenic glucosides present in cassava have to be reduced to safe levels before feeding to animals. Cassava root meal presents a problem in animal feed, as it is very dusty, a condition, which may lead to reduced palatability and intake, and ulcerogenic conditions. Some of the measures suggested for improving cassava root meal include addition of oil, molasses and pelleting.

This present study was carried out to evaluate different processing methods and feed formulations to address the above problems as a means of promoting the use of cassava in livestock feeds.

Materials and Methods

This study was conducted at the Department of Animal Science and Production of Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Three experiments were carried out using Large white and Landrace crosses of pigs. Economics of using cassava chips in pig rations was also evaluated. Carcass characteristics were also determined in all growth experiments.

Experimental procedures. In all trials, animals were dewormed two weeks prior to the start of the experiments and observed further for a period of 7 days. Feeding was done at 8 and 15 hours every day. Animals were allocated to dietary treatments by ensuring a balance of initial weight and sex. They were fed according to a standard scale. Water was supplied *ad libitum* during the day throughout the experimental period. Body weight changes were recorded weekly. Feed intake was recorded and feed conversion ratio (FCR) computed. The animals were slaughtered when they made 90 kg and their carcass characteristics determined. The

economics of pork production was also determined.

In experiment 1, twenty-four pigs weighing on average 33 kg each were allocated to four dietary treatments in a completely randomised design. Diet 1 was a control diet based on maize and sorghum as energy sources. Diet 2 was a complete diet based on cassava root meal (CRM); diet 3 was made of raw (peeled and soaked) cassava root fed separately with protein concentrate (cafeteria system), whereas diet 4 was based on rice polishing. Fresh cassava tubers were purchased from nearby farms and the varieties involved were all sweet viz. Kigoma, Mzungu, Msenene and Ndunga. In treatment 3, the tubers (CRT) were washed, peeled and soaked in static water for 24 hrs. Before being fed, the tubers were chopped. The pigs were first offered 1.0- 1.5 kg of the protein concentrate. After clearing, they were offered the peeled cassava semi-*ad libitum* by closely monitoring the daily intake so that no refusals were collected. Each day's feed offered was determined by feed consumption the previous day. The cassava root meal (CRM) was prepared by peeling the cassava, chopping, drying and milling. The hydrocyanic acid (HCN) content in the cassava root meal was determined. Metabolic studies were also done to determine the digestibility and metabolisable energy content of the diets, and nitrogen retention of the pigs. A 4x4 Latin square design was used. A preliminary period of 5 days was followed by a collection period of 7 days during which faeces and urine were collected.

In experiment 2, twelve pigs weighing on average 19 kg were allotted to three dietary treatments by sex, weight and litter. In treatment 1, the animals were fed fresh unpeeled cassava and protein concentrate (in the same way as diet 3 above). Cassava was fed semi-*ad libitum*. The protein mixture was fed at a rate of 1.0 – 1.5 kg/pig/day. Diets 2 and 3 each consisted of 55% peeled cassava root meal with different proportions of cotton seed/sunflower cake.

In experiment 3, eighteen growing-finishing pigs weighing about 18 kg were allotted to three dietary treatments; diet 1 was a control diet, diets 1 and 2 contained 67 and 78% hominy meal, respectively, while diet 3 contained 60% cassava chips from bitter varieties (mainly Kalolo). The chips were prepared from 2 villages (Miswe & Zogowale, Kibaha) using a specially designed cassava chipper. Diets 1 and 3 were formulated for A-Z Animal Feeds (Dar es Salaam) for use as commercial pig feeds.

Data analysis. DM, OM, CP, CF, EE, Ash, NFE, Ca and P of experimental diets were determined using standard procedure (AOAC, 1990). Data for growth rate, digestibility, FCR, economics of cassava diets and carcass characteristics were analysed according to the General Linear Model (GLM) of the Statistical Analysis System (SAS, 1998)

Results

Chemical composition and digestibility. The chemical composition of cassava and diets used in the study is shown in Tables 1 and 2. Fresh cassava tubers had DM content ranging from 34.4 to 38.3 %. Cassava had very low protein content and negligible amounts of amino acids. Cassava chips from bitter

varieties (Kalolo), which contained unpeeled cassava, had relatively high levels of crude fibre (3.6%). Unpeeled sweet cassava contained 3.3 % CF. Peeled sweet varieties of cassava had CF content of 2.8-3.5%. Peeling reduced the fibre and ash contents. The peels from sweet varieties contained 26.2% NDF, 5.8% ash and 5.4% CP and formed 20 % of the tuber. The ash content of unpeeled cassava was 3.3% while for peeled cassava it ranged from 1.6 to 3.1%. The starch content in peeled sweet varieties ranged from 81 to 88% while for the peel it was only 16 %. The hydrocyanic acid (HCN) content in CRM was 25 mg/kg.

The diets contained 13-18% CP. The digestibility of the diets was high (79.4 to 86.7 %DMD) and followed closely the crude fibre content of the diets. The results revealed that CRT diet and rice polishing diet were significantly ($P<0.05$) more digestible than the maize/sorghum diet and the CRM diets especially with respect to DM, OM and CP. Consequently the CRT and rice polishing diets had higher metabolisable energy (15.4 & 16.1 MJ/kg DM) than the rest of the rations.

Growth performance, feed intake and feed conversion efficiency of growing pigs. The daily gain, feed intake and feed conversion ratio of pigs are presented in Table 3. The highest feed intake and growth rate were

Table 1: Chemical composition of ingredients and diets used in experiment 1 and 2 (%DM).

Item	DM	OM	CP	CF	EE	Ash	NFE	Ca	Lys	Meth
Experiment 1										
Diet 1 (control)	91.2	89.7	17.9	19.6	6.2	10.5	54.9	0.7	-	-
Diet 2 (CRM)	92.1	84.4	15.6	7.8	2.5	5.9	68.1	0.7	0.6	0.5
Diet 3 (CRT)*	92.8	92.2	17.2	9.5	5.7	7.2	96.0	0.7	0.8	0.6
Diet4 (RP)	94.0	93.5	15.3	14.7	7.4	6.5	66.0	0.6	1.0	0.7
Prot. conc. (for diet 3)	92.9	88.3	32.7	10.3	7.8	11.7	37.5	2.2	1.5	1.1
Cassava tubers	34.4	96.9	2.1	3.3	0.6	3.1	91.1	0.1	-	-
Cassava root meal	89.0	-	2.4	3.5	0.5	1.6	93.8	0.7	-	-

*Based on DM consumption of 52% cassava root tubers.

CRM = Cassava root meal, CRT = Cassava root tubers (fresh), RP = Rice polishing, Prot.Conc = Protein concentrate, SC = Sunflower cake, CSC = Cotton seed cake, Lys= Lysine, Meth = Methionine+cystine.

Table 2: Chemical composition of ingredients and diets used in Exp 2 and 3 (%DM)

Item	DM	CP	CF	EE	NFE	Ash	Ca	p	Lys	Meth
Experiment 2										
Prot. conc	94.3	27.0	17.5	8.4	29.4	17.7	2.1	1.1	1.4	1.2
Cassava tubers	38.4	1.70	3.5	0.6	90.9	3.2	0.3	0.2	-	-
Cassava peels	93.4	5.4	-	1.3	-	5.8	0.8	0.1	-	-
Diet1* (CRT+CSC+SC)	92.3	13.9	10.4	4.5	61.7	10.4	1.0	0.6	0.6	0.5
Diet2 (CRM+CSC)	91.9	15.2	7.7	4.8	67.0	5.4	1.1	0.6	0.7	0.5
Diet3(CRM +CSC+SC)	93.2	13.4	11.8	4.2	61.4	9.11	0.9	0.6	0.6	0.6
Experiment 3										
Cassava chips	88.6	5.3	3.6	0.7	69.9	3.3	0.7	0.5	-	-
Diet1(hominy based diet)	94.8	14.2	9.8	2.3	53.7	7.2	0.75	0.6	-	-
Diet2 (hominy based diet)	95.0	15.1	9.9	5.2	54.1	7.3	0.8	0.6	-	-
Diet3(cassava based diet)	94.1	14.7	10.7	2.0	50.3	8.4	0.6	0.5	-	-

*Based on DM consumption of 56.2% fresh cassava roots and 43.8% protein concentrate.

observed in experiment 1. The diets in this experiment had the highest CP content. However, pigs in this trial had the poorest feed conversion. The other treatments were comparable. In experiments 1 & 2 pigs fed fresh cassava consumed 406 kg of cassava and 152 kg protein concentrate, and 383 kg of cassava and 112 kg protein concentrate per pig respectively, from 20 to 90 kg. The average daily gain in all the experiments ranged between 479 and 660 g/day. Feed intake was generally high in all experiments indicating that all diets were well formulated. The most interesting results were obtained in experiment 3 where the diet based on cassava chips outperformed the others. Feed conversion ratio was 2.6 as compared to 3.9 and 4.3 for the hominy meal based diets. Growth rate was also significantly higher for the cassava chips based diet. In experiment 1, pigs fed the soaked cassava consumed 3.49 kg of cassava and 1.2 kg protein concentrate. Pigs fed cassava diets developed skin lesions, which were more severe in the raw cassava group. Excessive soaking led to breaking of the starch and pigs disliked the cassava. In experiment 2, although the plan was to feed fresh raw unpeeled cassava, the pigs consistently peeled the

cassava, ate the parenchyma and left out the peels. It was therefore decided to peel the cassava before feeding. Pigs fed on fresh cassava tubers experienced reduced feed intake associated with scouring/gastrointestinal disturbances. The conditioned was well expressed in pigs with body weights less than 25 kg. Severe diarrhoea occurred during the 6th week. Pigs fed fresh cassava had severe skin lesions indicating deficiency of zinc.

Carcass characteristics and organ weights of pigs. Most of the carcass characteristics and organ measurements did not differ ($P>0.05$) significantly, though pigs fed on cassava diets tended to have leaner carcasses compared to other treatments. The carcass characteristics were closely related to the content of crude fibre in the diet. There were no significant differences in carcass characteristics and organ weights between sexes, though barrows tended to have thicker back fat, heavier kidney weight, shorter carcasses and less gut fill than gilts.

Economics of using cassava in pig rations. Table 4 shows the cost of production of pork

Table 3: Growth performance, feed intake and conversion efficiency of growing –finishing pigs.

Parameter	Dietary treatment				Se M
	Control	CRT	CRM	RP	
Experiment 1					
Initial weight (kg)	33.8	32.0	34.0	31.5	2.52
Final weight (kg,)	89.4	89.6	89.2	89.0	2.60
Feed intake g DM/pig/d	2581	2555	2437	2467	120.4
Daily gain (g)	625	635	658	660	46.90
Feed conversion ratio (FCR)	4.44	4.19	4.50	3.69	0.90
Experiment 2					
	CRT	CRM+SC	CRM+CSC+SC		
Initial weight (kg)	19.0	20.5	18.0		1.91
Final weight (kg)	89.8	89.8	90.3		0.48
Feed intake, g/pig/d	1873	2102	2025		120.10
Daily gain (g/d)	551.0 ^a	646.0 ^b	589.0 ^a		46.60
Feed conversion ratio	3.45	3.36	3.56		0.34
Experiment 3					
	Hominy meal based	Hominy meal based	Cassava based diet		
Initial weight (kg)	17.9	18.2	18.8		0.23
Final weight (kg)	58.8	61.4	64.6		0.46
Feed intake g DM/pig/d	2100	2000	1880		62.0
Daily gain (g/d)	479 ^a	515 ^a	546 ^b		42.4
Feed conversion ratio	4.3	3.9	2.6		0.12

^{ab}. Values within rows bearing different superscripts are significantly different (P<0.0.5).

Table 4: Economics of using cassava in pig diets.

Parameter	Dietary treatment		
	1	2	3
	Hominy based diet	Hominy meal based diet	Cassava based diet
Feed cost/kg (Tshs)	100	100	97
Feed/pig,kg	175.9	168.5	131.7
Feed Cost per pig Tshs	17590	16850	12775
Labour + Medication cost/pig (Tshs)	11830	11830	11830
Total Revenue/pig (Tshs)	43800	46400	49600
Total cost/pig (Tshs)	29420	28680	25605
Net profit/pig (Tshs)	14380	17720	23995

using different diets. The diet based on cassava chips which had the best performance showed higher returns and lower cost of production. Consequently it produced higher gross margins and net profit.

Discussion

Chemical composition and digestibility. The DM in cassava root meal and chips of 89 % is comparable to values obtained by Lekule *et al.* (1990), Tewe (1994), Shrestha (2002) and Mutayoba *et al.* (2003). The low content of protein (1.7-3.3%) in cassava in the present work is similar to that reported by other workers (Sommert *et al.*, 1999 and Kainjanapruthipong *et al.*, 2001). Lekule *et al.* (1990) have documented slightly higher values ranging from 2.8 to 4.6 %. Cassava is deficient in protein; this is because about 40 to 60% of the total N is in the form of non-protein nitrogen (NPN). Cassava was inferior to rice polishings and maize in protein and amino acids content. Values obtained in this study are similar to values documented by Wyllie and Lekule (1980). The observed high Ash and CF in unpeeled cassava is partly influenced by the degree of contamination with soil. In addition, the variation could be attributed to differences in the method of processing and moisture content. However, the values are invariably lower than values reported by Lekule *et al.* (1990) for CRM. Peeled cassava had very high content of NFE (91-94%) while unpeeled cassava contained 70% NFE. This is in line with the work of Sommert *et al.* (1999) that well prepared CRM from peeled tubers contain about 90% NFE. The range of CP content between 13.5 and 18% of the diets used in the present experiments was within the dietary CP of 14 to 18% recommended by NRC (1979) for growing-finisher pigs. The higher CF in most of the diets can be attributed to high content of such component in sunflower cake, sunflower seed cake and unpeeled cassava incorporated in the formulation of such rations.

Growth performance, feed intake and conversion efficiency of growing pigs. The overall growth rate observed in this study was relatively high and comparable to that of Oke (1984). In experiment 3, the diet which had cassava chips, had better feed conversion ratio compared to hominy meal based diets. The mean value for diet 3 (2.6%) was slightly lower than 2.8 % reported by Israel (1992) who fed cassava root meal to pigs. The use of cassava root meal did not significantly reduce feed intake. Lekule *et al.* (1992) observed only slight reduction in intake in CRM diets although Muller *et al.* (1974) reported that cassava based diets have ulcerogenic effects upon the mucosa and cause irritation to the eyes and respiratory organs leading to reduced intake. The lower intake and gains in pigs fed raw cassava could be due to inability of the relatively young pigs to cope with the bulk and low palatability. It is also possible that the diarrhoea, which could be a result of HCN in the fresh cassava, leads to lower feed intake and growth rate (Gomez, 1977). This finding suggests that fresh cassava should not be introduced to young pigs of less than 20 kg live weight and only moderate amount up to about 30 kg live weight. The possible cause of the skin lesions is mineral deficiency especially zinc as demonstrated by Maust *et al.* (1992) leading to parakeratosis. Fortification of cassava based diets with fat; Vitamin B₁₂ has proved to improve pig performance fed cassava (Hutagalung, 1977). Skin lesions, which occurred when pigs were fed 45-60% cassava, were alleviated following a double dose of vitamins and minerals. The low mineral and vitamin content in cassava coupled with the use of some nutrients (methionine + cystine and cobalt) for detoxification and high levels of oxalic acid in cassava roots renders these minerals unavailable. Oxalic acid reduces the availability of Ca and P. The incidence of diarrhoea in young pigs fed cassava has been observed by Maust *et al.* (1972). Hew and Hutagalung (1977) have suggested that scouring occurs if pigs are fed cassava high

in HCN. The peeling of the cassava by pigs fed on fresh cassava is a clear indication that sweet varieties of cassava have the HCN concentrated in the peel. Peeling removes most of the cyanide in sweet varieties. It is documented by CIAT (1978) that the total cyanide in the cassava peels is about 15 to 20 times higher than in the parenchyma in sweet varieties and about twice in bitter varieties. Ways of detoxifying cassava include peeling, boiling, chopping and drying, soaking or fermentation. Chopping of the tubers initiates the action of the enzyme linamarase on the hydrolysis of glucosides, resulting in HCN liberation (Gomez, 1977). Simple drying of sliced roots was shown to be capable of removing up to 90 % HCN and meal produced from bitter varieties had relatively low HCN contents (100-150 ppm on DM basis) (Gomez, 1977).

Cassava diets present a problem of palatability and ulcerogenic effects. The addition of sugarcane molasses (Wyllie and Lekule, 1980), fat, fishmeal, pelleting (Muller, 1977) have been found to improve palatability resulting in higher feed consumption and faster growth rate. In the present study, chopping and soaking the cassava for one day seemed to be effective in reducing the HCN to insignificant levels. For commercial utilisation of cassava, dustiness must be avoided; hence cassava root meal is not suitable. The results of experiment 3 are interesting. Using cassava chips processed with a cassava chipper produces cassava of the right particle size. These chips do not need further milling and dries within a short time.

Economics of using cassava in commercial feeds. The economic analysis (Table 4) showed that feeding growing pigs with cassava-based rations was cost-effective. This is reflected in the low feed conversion ratio and high growth rate of pigs fed cassava chips based diet. The economics of using cassava will depend to a large extent on the availability and cost of alternative energy sources.

Digestibility. The higher digestibility of cassava based diets compared to the control (maize/sorghum) is supported by the results of Sonaiya and Omole (1982) who reported that cassava diets had a higher digestibility of DM and energy than sorghum diets. However, the coefficients of digestibility were much lower than those observed in this study. The higher digestibility of cassava-based diets has been suggested by Gomez and Valdivieso (1983) to be caused by physio-chemical characteristics of cassava starch granules.

Carcass characteristics and organ weights of pigs. Pigs fed on cassava diets tended to deposit less fat as exhibited by lower kidney fat. These findings concur with those of Sonaiya *et al* (1982) that the highest level of cassava diets produced leaner carcasses. Pigs fed on fresh cassava and cassava root meals had thinnest back fat. However, this was more a reflection of the fibre content in the diet. Most organ measurements were not significantly ($P>0.05$) influenced by cassava a fact supported by results of Sonaiya *et al*. (1982).

On the other hand, heavier thyroids observed for the control diet group could be caused by high proportions of goitrogenic substances in diet 3 than in the other diets.

Conclusions

The following conclusions can be drawn from the present study:

1. For small scale pig producers in cassava growing areas, raw, sweet varieties can be fed to finishing pigs. Peeling, which is labour intensive can be avoided, as the pigs will peel them. Alternatively, the cassava can be soaked for one-two days and be fed to growing finishing pigs. About 390 to 406 kg of cassava and 112 to 152 kg protein concentrate (25-35%CP) are required to raise a pig from 20kg to 90 kg.

2. For good performance, cassava based diets must be well fortified with high quality protein, minerals and vitamins to avoid deficiency symptoms.
3. Cassava can be used in commercial pig rations cost-effectively. To eliminate the problem of HCN toxicity and avoid dustiness, the most appropriate processing method is the use of cassava chipper, which produces cassava chips of the right particle size.

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Nutritional evaluation of composite flour based on root and tuber crops and sensory acceptability of the developed products

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Abstract. A study was conducted to evaluate the nutritive value of composite flour based on root and tuber crops and sensory acceptability of the developed products. Fresh tubers and roots of cocoyam, sweetpotato and cassava, respectively, were washed separately, peeled and sliced. The sliced pieces of each crop were soaked separately in water for 1-2 h to reduce toxic and anti-nutritional factors and sun dried for 4-5 days. The dried slices were milled and sieved. The flour was used in the formulation of six types of composite flour for the preparation of baked products and weaning foods. The formulated mixtures included: cocoyam: wheat: soybeans (50:20:30), cassava: wheat: soybeans (50:20:30), sweetpotato: wheat: soybean (50:25:25), cocoyam: maize:soybean (50:20:30), cassava: maize: soybean (50:25:25), sweetpotato: maize: soybean (50:25:25). The nutritive content of formulated flour mixtures contained 9.96 to 15.60, 67.98 to 74.11, 2.57 to 3.19 and 1.66 to 2.89 percent of protein, carbohydrate, fat and crude fibre, respectively. Mineral content of formulated mixtures ranged from 13.0-480.0 mg/100g for iron, calcium, phosphorus, and magnesium while the energy value ranged from 360.07 to 363.13 kcal. Sensory acceptability of the products developed from the formulated flours was carried out to assess taste, texture, smell, colour and general acceptability using a five point hedonic scale. Breads and porridges prepared were generally accepted in terms of taste, texture, smell and

colour. It was therefore concluded that flour from root and tuber crops can be blended with cereal and legume flours to produce weaning foods and baked products.

Introduction

Root and tuber crops refer to any growing plant that store edible materials in subterranean roots, corm or tuber. Root and tuber crops play a very important role in food security, as they are tolerant to environmental stress and produce reasonable yields under marginal soil conditions. Root and tuber crops are basic to diets of millions of people of temperate zones and vast areas of tropics and subtropics where most of the world's undernourished people live (FAO, 1990). In West Africa root and tuber crops are very popular and are consumed in large quantities. The technology of "gari" processing has accelerated the development of root and tuber crops in West Africa (FAO, 1990).

Generally, root and tuber crops require little care and other inputs used in production and have relatively fewer pests and diseases compared to cereals and legumes. In Tanzania these crops are mainly intercropped with other crops like legumes (beans, peas and cowpea). Cassava is usually intercropped more frequently than other crops such as sweetpotato and cocoyam. The crops are usually subsistence, grown mainly as food for farmers and only selling the surplus. They are largely consumed in fresh form after

boiling or roasting. Limited amounts of these crops are dried to produce flour which is used to prepare stiff porridge “ugali”. Cassava is fermented and dried to produce “makopa” and “udaga”, sweetpotato is dried to produce “michembe” and boiled and dried to produce “matobolwa” (Mlingi, 1995). Cocoyam is rarely dried.

Roots and tubers normally undergo some form of processing and cooking before consumption. The methods of processing and cooking ranges from simple boiling to elaborate fermentation, drying, grinding to make flour, depending on the varieties of roots and tubers (Akaroda, 1999). Processing of root and tuber crops provides a range of utilizable products, reduces post harvest losses, enhances the taste of the products and eliminates anti-nutrition factors like cyanide (Akaroda, 1992).

The nutritional value of root and tuber crops (cassava, cocoyam, sweetpotato, yams) lies in their ability to provide one of the cheapest sources of dietary energy in form of carbohydrate. They are also good sources of dietary fibre. In developing countries as a whole, they provide 9% of the total calorie intake (Onwueme, 1994). In some regions, particularly in parts of equatorial Africa they contribute almost half of the total calories consumed (FAO, 1990). Potato and sweetpotato contain substantial levels of protein, vitamins and minerals although other root and tuber crops are relatively low in protein (Akaroda, 1992).

Historically, governments and research institutions have paid little attention to root crops as compared to grains. These crops have been regarded as inferior and produced and consumed only by the subsistence farmers in the developing parts of the world. However, in recent years tropical root and tuber crops have gained interests by research communities and others who are concerned with food and nutrition problems of low income people. There is an increase in scientific research and investigation in well established research centres like International Institute of Tropical Agriculture (IITA),

International Centre for Tropical Agriculture (CIAT), International Potato Centre (CIP) (Janick and Simmon, 1990). Therefore, the objective of this study was to formulate composite flours using root and tuber crops in combination with cereals to develop various utilizable options. Composite flour using different proportions of cassava, cocoyam and sweetpotato with wheat, maize and soybeans were used in preparation of weaning foods and breads.

Materials and Methods

Materials. Fresh roots and tubers of cassava, cocoyam and sweetpotato used in this study were purchased from Morogoro Municipal market. Wheat, maize, and soybean flour, cooking oil (Korie), yeast, and sugar were purchased from Pira Cash and Carry Supermarket in Morogoro Municipality, Tanzania.

Sample preparation. Fresh roots and tubers of cassava, cocoyam and sweetpotato were washed separately to remove soils and other debris. They were then peeled, sliced cross sectionally into 3 - 5mm slices using clean knife. In case of cassava, the mid-rib was removed. The sliced pieces of each crop were soaked separately in water at a ratio of 1:3 (crop:water) for 1-4h. The soak water was discarded after which the samples were spread thinly on mats and sun-dried under shade for 4-5 days. The dried samples were milled into flour. The flour was used in formulation of composite flour, which was used to prepare bread and porridge.

Formulation of composite flour. The three types of flour obtained were used to formulate composite flour based on energy requirements. According to Protein Advisory Group (1973) six formulations of different proportion were prepared as follows:

- A Cocoyam:wheat:soybeans (50:20:30)
- B Cassava:wheat:soybean (50:20:30)
- C Sweetpotato:wheat:soybean (50:25:25)

- D Cocoyam:maize:soybeans (50:20:30)
- E Cassava:maize:soybeans (50:25:25)
- F Sweetpotato:maize:soybeans (50:25:25)

Formulations (A,B and C) were used in making bread, while formulations (D, E and F) were used to prepare porridge, each formulation contained a total of 500g.

Analyses. Nutrient composition of the six types of composite flours was carried at Sokoine University of Agriculture in the laboratories of Food Science and Technology, Animal Science and Soil Science Departments. Proximate composition were determined in duplicate using the standard procedures described by Association of Official Analytical Chemists (AOAC, 1995) methods. The moisture content was determined by drying using an air oven (WTC binder type E115 RWF 12/5 at 130°C) for 1 h (method 930.1). Crude protein was determined by the micro Kjeldahl, method 955.04 (% protein = $N \times 6.25$); the crude fat content was determined by soxhlet extraction (method 972.28); the crude fibre content by dilute acid and alkali hydrolysis (method 930.10), the ash content by using muffle furnace (Carbolite type RWF12/5 Sheffield, England) at 600°C for 2h to constant weight (method 942.05).

The carbohydrate content was determined by difference. The energy content was determined by multiplying percentages of crude fat, crude protein, and carbohydrate by factors of 9,4, and 4 respectively (Egan *et al.*, 1981).

The amounts of calcium, magnesium, phosphorus, and iron of the six formulations were determined in duplicate by using an automated atomic absorption spectrophotometer model 3030 (Perkin Elmer Norwalk Connecticut, USA) (method 967.21).

Bread preparation. To 500 g of formulation A which contain cocoyam: wheat: soybean, one table spoon of instant yeast, 2 table spoons of sugar, 3 table spoons of cooking oil and a pinch of salt, were added. The mixture was kneaded into soft dough. The dough was

covered with a clean white cloth and left to rise (about 1 h). After rising the dough was kneaded again and small portions were cut, kneaded and placed in baking tins, where they were left to rise again (20 - 30 minutes) then baked in pre-heated oven at 200°C for 20 minutes. They were removed from the oven placed on dry clean trays to cool. The same procedure was repeated for formulations, B (Cassava: wheat: soybeans) and (Sweetpotato: wheat: soybeans).

Porridge preparations. A litre of clean tap water was poured in a saucepan and brought to boil. Two hundred grams of sample D flour (Cocoyam: Maize: Soybean) was added to the pan while stirring. The mixture was heated while continuously stirred to avoid formation of lumps until boiled, 3 table spoon sugar was added and allowed to boil for 10 minutes. Porridge was poured in a thermos flask ready for sensory evaluation. The procedure was repeated for sample E and F.

Testing of bread samples. The bread samples were sliced into 3 – 4 mm slices. Each slice was coded with 3 digit numbers and presented to 20 semi trained panellists. The panellists consisted of Sokoine University of Agriculture staff and students from the Department of Food Science and Technology. The panellists were asked to evaluate taste, smell, texture, colour, and general acceptability using 5 point hedonic scale where 5 represented the highest order of preference and 1 the least order of preference as described by Larmond (1977).

Statistical Analysis. Data obtained were subjected to analysis of variance using MSTAT C statistical software package (Freed *et al.*, 1990) and mean separation done using Duncan's Multiple Range Test (Snedecor and Cochran, 1990).

Results and Discussion

Nutrient composition of the formulated composite flour. The results in Table 1 and

Table 2 show that there was a significant difference ($P < 0.05$) between the tested samples. The protein content of the composite flour formulations ranged from 9.96 – 15.60%. These results show that mixing of legumes, such as soybean and cereals like wheat with sweetpotato, cassava and cocoyam crops have a great influence on the protein level of the resulting mixtures. Soybean is often times used in preparation of infants formulae due to its high content of protein (30-46%) and fat (12 - 14%) (Annan and Plahar, 1995). The results in Table 1 show that the protein in the formulated flour satisfies the requirements for bread baking flour which is about 10 - 12% protein as reported by West *et al.* (1988). The results in

Table 2 show that the protein content of the formulated composite flours (13.15-15.6%) falls within the range of protein requirements for babies, which is 15% as recommended by Codex Alimentarius Commission (1994). These results support FAO reports (1990), which show that cocoyams contain high protein content, followed by cassava and lastly sweetpotato.

Fat content of formulated composite flours ranged from 2.57 to 3.19% (Tables 1 and 2), which is lower than 10 – 20% recommended fat for the formulation of supplementary foods (Anna and Plahar, 1995). However, the fat content of the formulated composite flour in this study is close to wheat flour (2%) as reported by West *et al.* (1988).

Table 1: Nutrient composition of composite flours for baking (in dry basis).

Composite flour	Crude protein	Crude fibre	Crude fat	Carbonhydrate	Ash	Ca	Mg	P	Fe
	%				mg/100g				
Cocoyam: wheat:soybean (50:20:30)	13.26a	2.04a	2.73b	70.98c	2.64a	320b	150b	460a	15.20a
Cassava:wheat:soybean (50:20:30)	9.96c	1.92b	2.83a	74.11a	2.51b	320b	150b	430b	15.00a
Sweetpotato:wheat:soybean (50:25:25)	12.22b	1.66c	2.57c	72.78b	2.51b	330a	190a	390c	14.30a

Means followed by the same superscript letter within the column indicate no significant difference ($P > 0.05$) according to DMRT.

Table 2: Nutrient composition of composite flours for weaning foods (in dry basis).

Composite flour	Crude protein	Crude fibre	Crude fat	Carbonhydrate	Ash	Ca	Mg	P	Fe
	%			mg/100g					
Cocoyam: wheat:soybean (50:20:30)	15.6a	2.65c	2.88c	67.98c	1.91c	360.00a	200.00a	480b	14.30a
Cassava:wheat:soybean (50:20:30)	14.28b	2.89a	3.19a	70.26a	2.97a	320.00b	160.00b	479.20a	14.70a
Sweetpotato:wheat:soybean (50:25:25)	13.15c	2.83b	2.83b	68.83b	2.94b	300.00c	130.00c	460.00c	13.00b

Means followed by the same superscript letter within the column indicate no significant difference ($P > 0.05$) according to DMRT.

On the other hand the fat content in the tested samples is not likely to cause rancidity in the flour when stored at room temperature.

The crude fibre of the formulated composite flours show significant difference ($P > 0.05$) and ranged from 1.66 – 2.89% (Table 1 and Table 2). These values are in accordance with the allowable levels of food fibres of 1.6-2.8% as reported by FAO/WHO (1971). The results of the present study show that the fibre content of the composite flour for weaning formulations (Table 2) agree with the crude fibre of 2.5% recommended by Protein Advisory Group (1973).

The carbohydrate content of the formulated composite flours in the present study (Table 1 and Table 2) is within the range required for wheat flour for bread baking and weaning food mixtures which is between 60 - 90 % dry weight basis (West *et al.*, 1988). Physical properties of starch grains influences the digestibility and processing qualities of root and tuber crops. Most of the starch granules like those in cocoyam are very small which improves the starch digestibility, hence making the flour suitable for infants and invalids food formulations (FAO, 1990). The results for calcium, phosphorus and iron

of the formulated composite flours vary significantly ($P > 0.05\%$) (Table 1 and Table 2). Calcium content of the formulated flours is within the range required for wheat flour and for weaning food formulations. Felicity (1993) recommended that the calcium content for infants weaning foods is 400 mg/100g, which is sufficient when an infant is able to take at least 300g of the weaning mixture per day.

Sweetpotato: maize: soybean (50:25:25) mixture had the lowest total energy 360.07 kcal while that of sweetpotato: wheat: soybean (50:25:25) had the highest total energy of 363.13 kcal (Table 3). Among the formulated composite flours in this study cocoyam: cassava and sweetpotato with wheat and soybean flours respectively (Table 3) were within the recommended values of flour for bread baking of about 340 kcal as recommended by West *et al.* (1988). The energy content of the formulated mixtures for weaning food (cassava/sweetpotato/ cocoyam : maize : and soybean) is in accordance with the recommended energy values of 360-400 kcal (Codex Alimentarius, 1994).

Generally the composite flour obtained in this study have added advantages

Table 3: Energy content of formulated composite flour (kcal).

Composite flour	Protein	Fat energy	Carbohydrate	Total
Cocoyam: wheat:soybean (50:20:30)	53.04	24.57	283.92	361.53
Cassava:wheat:soybean (50:20:30)	39.82	25.47	296.44	361.73
Sweetpotato:wheat:soybean (50:25:25)	48.88	23.13	291.12	363.13
Cocoyam:maize:soybean (50:25:25)	62.40	25.92	271.92	360.24
Cassava:maize:soybean (50:25:25)	52.60	28.71	281.04	362.35
Sweetpotato:maize:soybean (50:25:25)	57.14	27.92	275.32	360.07

nutritionally in terms of protein, carbohydrate, and minerals, but low in fat content which is compensated in energy content, showing that all six formulations were within the recommended energy required for baked and weaning foods.

Sensory acceptability of the products prepared from composite flour.

Sensory acceptability of the bread made from the composite flour of cocoyam: wheat: soybean, cassava: wheat: soybeans, and sweetpotato: wheat: soybeans show that there was no significant difference ($P < 0.05$) in taste texture, colour and general acceptability (Table 4). However, significant ($P > 0.05$) variation was observed in smell of bread prepared from sweetpotato: wheat: soybean mixture compare to bread prepared from cassava and cocoyam: wheat: soybeans (Table 4). Generally some of the panellists (40%) reported that the breads had some beany smell which was not liked much. The beany smell was due to the presence of soybeans flour in the mixture as reported earlier by Protein Advisory Group (1973) that legumes contain strong smell which affect the acceptability of the products. The results in Table 5 show that there was no significant difference ($P < 0.05$) in texture, smell and general acceptability in all the porridge samples prepared from the formulated root

and tuber composite flour in this study. However, significant differences ($P > 0.05$) were observed in taste and colour of porridge prepared from cocoyam:maize ;soybeans as shown in Table 5.

Conclusion

The results of this study show that formulation of composite flour of root and tubers such as cocoyam, cassava and sweetpotato up to 50% with cereals (wheat and maize) and legumes (such as soybeans) are good sources of carbohydrate therefore, they may be adopted as an alternative and cheap source of energy for most people. Also the mixtures are good source for protein, crude fibre, and minerals including calcium, and magnesium. Hence root and tuber flour can be used in Tanzania to substitute for wheat flour in producing good composite bread products and with cereals such as maize to produce weaning mixtures, which will ensure food security.

Bread and porridge prepared from formulated root and tuber composite mixtures were generally accepted suggesting that root and tuber crops can be utilized in form of breads, both for adults and children, and porridge for children under five years and school children. These products need to be

Table 4: Mean scores of breads made from root and tuber based composite flours.

Sample	Taste	Texture	Smell	Colour	General acceptability
Cocoyam:wheat:soybean	3.0a	3.10a	3.5a	3.20a	3.05a
Cassava:wheate:soybean	3.53a	3.89a	3.5a	4.16a	3.60a
Sweetpotato:wheat:soybean	3.15a	3.79a	2.8b	3.05b	3.16a

Table 5: Mean scores of porridges from root and tuber based composite flours.

Sample	Taste	Texture	Smell	Colour	General acceptability
Cocoyam:maize:soybean	2.8b	3.8a	3.4a	2.8b	3.2a
Cassava:maize:soybean	3.9a	4.3a	3.8a	4.0a	4.2a
Sweetpotato:maize:soybean	3.7a	4.0a	3.2a	3.3a	3.8a

promoted and encouraged in the communities, which grow these crops. This will help to reduce the dependence on cereal crops in the household food security.

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Rural household expenditures for roots and tubers in South Western Nigeria: An almost ideal demand system analysis

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Abstract. This paper analyzes rural household expenditure patterns on root and tuber-based products in the forest and savanna zones of southwestern Nigeria. A multistage sampling technique was used to select 252 respondents in two communities during the 2001-2002 period. Daily data on household expenditure were collected over two weeks in each quarter of the year. In addition, demographic characteristics of households were collected. Data were analyzed using descriptive statistics and the Almost Ideal Demand System (AIDS) model. Respondents' mean age was 42 years in the forest and 54 years in the savanna. Education level was low: only 8.3 years (forest) and 4.52 years (savanna). Mean household size was 7 in the two ecologies. Household expenditure was 83% of mean income in the forest and 100% in the savanna. Contrary to expectations, food accounted for 21.5% of household expenditure for the forest and 15.5% for the savanna despite a major share of harvest being used for home consumption. Major root and tuber-based products identified were: *gari/eba*, cassava flour, *fufu*, *amala*, boiled yam, pounded yam, and cocoyam. There was no major difference in household budget expenditure patterns on these commodities in the two ecologies, though the total budget allocation to roots and tubers was higher in the forest zone. Own price elasticity estimates show that some products are price elastic, many are income elastic, while others have positive cross price

effects (substitutes) or negative effects (complements). Demographic factors significantly influenced decisions on household budget allocation, particularly in the forest zone. Budget shares and elasticity estimates of commodities may assist in the construction of cost of living indices. Linking farmers to growth markets will ensure sustainable root and tuber production to meet the country's food sufficiency objective.

Introduction

Improving rural food security, income, and nutritional status requires an understanding of the food demand structure of the households. The increase in global population from 5.7 to 7.5 billion people and the growing urbanization particularly in developing countries have placed tremendous pressure on the global food system (Pinstrup-Andersen *et al.*, 1999). This suggests the need to produce more food and to provide increasing percentages of that output to urban areas while still attending to the needs of rural dwellers. Food crop production remains the main source of income for a large majority of households in Nigeria. However the rural households with their limited income and unlimited expenditure profile have to make choices from among alternatives in a manner that is consistent with the evaluation of their self-interest. This choice is guided by the utility derived from the consumption of goods and services, and households allocate income

among the various goods and services to be consumed in such a manner that the marginal utility per price of all goods and services consumed is equal (Nweke *et al.*, 1994). Thus, food crops are constantly evolving, not only in terms of genetic makeup but also with respect to the changing pattern of expenditure on the food items and the social, economic, and environmental relationships with the people who grow, sell, and consume them. This fact applies more emphatically to roots and tubers such as cassava (*Manihot esculenta*), potatoes (*Solanum tuberosum*), sweetpotato (*Ipomoea batatas*), and yams (*Dioscorea* spp.). According to Scott *et al.* (2000), over two billion people in the tropics and subtropics depend on roots and tubers for their sustenance and livelihood. In 1995-1997, farmers in developing countries harvested 439 million tonnes of the major roots and tubers cassava, potato, sweetpotato and yam with an estimated annual value of more than US\$41 billion, nearly one-quarter of the value of the major cereals.

These crops deserve particular attention because many of the poorest and most food insecure households in the developing world look to these crops as the principal source of food, nutrition, and cash income. They provide diversity in diet: as a vegetable for some, a basic calorie source for those less affluent, and an additional source of essential micronutrients for many. Producers are increasingly inclined to exploit their potential as animal feed, as sources of starch and speciality foods, and as competitors to grains (Alexandratos, 1995; Best 1996). The adaptation of roots and tubers to marginal environments and their great flexibility in mixed farming systems make them an important component of a targeted strategy that seeks to improve the welfare of the rural poor and to link smallholder farmers with the emerging growth markets. This could be achieved through the efficient and environmentally sound production of different high quality, and competitive products for food, feed, income, and industry. In addition, farm households see the value of

roots and tubers in their ability to produce more edible energy/ha/day than other commodities and in their capacity to generate yields under conditions where other crops may fail. Therefore, the importance of roots and tubers on consumption behavior in any rural household budget cannot be overemphasized.

This paper analyzes the expenditure pattern of rural households on root and tuber-based products in two agro-ecological zones of southwestern Nigeria with the aim of improving the food security and nutritional status of households as well as alleviating rural poverty.

Research Methodology

The study was conducted in two communities in two ecological zones of southwestern Nigeria. Akinlalu (rain forest) is in Ife North Local Government Area (LGA) of Osun State, with a population of 20388 by 1991 provisional census figures (NPC, 1991). Ilero (derived savanna) is in Kajola LGA, Oyo State, with a population of 36283 by 1991 provisional census figures (NPC, 1991).

A multistage sampling technique was used to select 252 respondents in the two communities, 2001-2002, the primary sampling unit was the household (the number of persons living under the same roof and eating from the same pot). A list of household heads was generated; and 123 were selected in Akinlalu and 129 in Ilero, based on age, gender, and wealth categorization.

Primary data were collected over two weeks in each quarter for one year with the aid of a structured questionnaire. This frequency of data collection was meant to take into consideration the seasonality in crop production which is the basis for food supply. During the course of the survey, daily data were collected on items of income and expenditure, types of food consumed, and their quantity/value in the household. Demographic and socioeconomic data on households were collected once a year and checked for any change during the quarter

sessions. Secondary data on household statistics were obtained from the LGA secretariats, State Ministries of Agriculture and Agricultural Development Projects (ADPs).

Data were edited and analyzed using descriptive statistics to describe the socioeconomic characteristics of the respondents and household resource structure, and the Almost Ideal Demand System (AIDS) model was employed to analyze the expenditure pattern of the households. The AIDS model specified makes possible the empirical measurement of the standard relationship between food consumption, commodity prices, income, and household characteristics by a system of budget shares (Deaton and Muellbauer 1980). It is expressed as follows:

$$W_i = \alpha_o + \sum_c \alpha_{ic} H_c + \sum_j \lambda_{ij} \ln(P_j) +$$

$$\beta_i \ln\left(\frac{X}{P^*}\right)$$

Where:

W_i = Budget share of the i th commodity;

X = Total expenditure on roots and tubers;

P_j = Price of root and tubers;

H_c = Household characteristics (e.g. age, gender, education);

P^* = (Stone price index) defined as $\sum w_j \ln P_j$;

α , β , and λ = Coefficients to be estimated (with α_o being the intercept; α_{ic} the coefficient of household characteristics, β is the income elasticity of demand which determines whether root and tuber-based products are luxuries or necessities).

Note that with

$$\left(\frac{X}{P^*}\right) = \frac{X}{\sum w_j \ln P_j}$$

the effect of P_j is reduced when logged such that w_j becomes paramount.

In effect, $\frac{X}{\sum w_j}$ relates quantity

demand to income; λ measures the change in the i th budget share following one

proportional change in P_j with $\left(\frac{X}{P^*}\right)$ held

constant. Thus, relative price changes work through this term. Thus, a commodity for which λ is negative (positive) has an own price elasticity greater (less) than 1 in absolute value. When λ is positive (negative), the commodities are considered substitutes (complements).

There are however, restrictions on the parameters of the AIDS equation that are required to make the model consistent with demand theory (Deaton and Muellbauer 1980). That is,

(i) $\sum_i \alpha_i = 1$; (ii) $\sum_i \lambda_i = 0$; (iii) $\sum_i \beta_i$; (iv) $\sum_j \lambda_{ij}$; and (v) $\lambda_{ij} = \lambda_{ji}$

Restrictions (i to iii) imply the adding up condition of the model. Homogeneity and symmetry of the model are satisfied if equations (iv) and (v) apply respectively. From the micro-model in equation (1), the following are obtained: the expenditure elasticity (E_i), uncompensated own (E_{ii}) and cross-price (E_{ij}) elasticity (Teklu and Johnson, 1988; Ahmed and Shams, 1994):

$E_i = 1 + (\beta_i/w_i)$; $E_{ii} = (\lambda_{ii} - \lambda_{ij})/w_i - 1$; $E_{ij} = (\lambda_{ij} - \beta_i w_j)/w_i$; and $E^{Hij} = E_{ij} + w_j E_i$.

The AIDS model is being used for modelling household behavior because of its theoretical consistency with the postulate that households maximize utility (minimize cost) in their decision process and its flexibility to encompass broad ranges of behavior. The AIDS methodology is widely used in empirical demand research because

it satisfies the requirements of demand theory and allows a complete matrix to be obtained of own-price, cross-price, and expenditure elasticities (Soe *et al.*, 1994; Zeller and Minten, 2000). As the relative change in a variable associated with a relative change in another variable, elasticities, are dimensionless measures of household behavior and are therefore better employed for general interpretation than the basic parameters. According to Timmer *et al.* (1983) and Pindyke and Rubinfeld (1998), elasticities computed from cross-section data are generally interpreted as long-run parameters that reflect the adjustment of all variables causing households to be different.

In the AIDS system, the explanatory variables are in log form (except for demographic characteristics). Thus, each coefficient represents the effects on the dependent variable of a one percent change in the explanatory variable. Since the dependent variable is budget shares, the estimated parameters are occasionally very small (Savadogo and Brandt, 1995). Additionally, the sign of the coefficients does not have the same meaning as in demand systems where the dependent variables are in expenditure or quantity form. For instance, a negative income coefficient implies that the corresponding income elasticity is less than unity and not necessarily that the corresponding good is inferior. The constant term or intercept represents the average value of the budget share in the absence of price

and income effects, while the F and R² values respectively measure the degree of significance and goodness of fit of the models.

Results and Discussion

Socioeconomic characteristics of respondents. The socioeconomic characteristics of respondents are shown in Table 1. The age of the household head varied between the mean of 54 years (forest) and 42 years (savanna). For the two agroecologies the male-headed households are in the majority (98.4% in the forest and 86.8% in savanna) as a consequence of the local culture. The economic implication is that men have ownership and command over farm resources while women have only user rights as a result of marriage.

The average level of education of respondents is very low: 8.3 years (forest) and 4.52 years (savanna). The difference between the mean years of education was statistically significant at the 5% level of probability. Household size varied between 1 and 33 (forest) and 1 and 24 (savanna) with a mean of about 8 in the two agroecologies. Household size determines the labor supply within the farming systems in the study area and it also influences household consumption expenditures. A mean farm size of 5.9 ha was recorded for the forest zone while 4.7 ha was obtained in the savanna. Respondents ascribed the seemingly large size of cultivated

Table 1: Selected socioeconomic characteristics of sampled households.

Characteristics	Forest	Savanna	t-value
Age (years)	53.60	41.75	6.31 ^a
Sex male (%)	98.4	86.8	0.348
Years of education of household head	8.30	4.52	5.12 ^a
Household size (No.)	8.32	7.85	0.70
Farm size (ha)	5.9	4.7	1.10
N	123	129	

N = sample size

Source: Data analysis 2003

Note: ^a = significant at p < 0.01.

farmland to extension into marginal lands, arising from increased farm population, while some of the farmers have ventured into commercial production.

Cash expenditure patterns of households. The total income used in household consumption expenditure was N244577 (forest) and N193478 (savanna). This amount corresponds to only Naira84/day/person (US\$0.7) for the forest and Naira66/day/person (US\$0.55). Therefore, households in these ecological zones are generally poor according to the World Bank indicators (World Bank, 2003).

Total household cash expenditure consists of expenditure on food and nonfood items such as housing, clothing, health, education, and infrastructure services, among others. In the forest zone, food is the largest item in household budgets accounting for 21.5% of all expenditure while savings followed closely with a budget share of 21.4%, festivities and ceremonies (9.8%), clothing (8.8%), and education (8.6%) in descending order of importance. Respondents claimed that the high percentage recorded for food is to complement the food supply from their own production. Savings are needed to reserve some of their farm harvests for the next seasons' production, since their previous savings were used in the current year's production operations. This implies that about 79% of the budget is really used on household consumption expenditure when the savings are made.

The high level of household cash expenditure on education suggests that respondents in the forest community recognize the need to educate their wards, even though the level of education was higher than that recorded in the savanna. The low figure recorded for housing (0.23%) may be explained by the fact that most of the respondents either owned their houses or resided in their family compound. Respondents in the forest zone do not depend on pipe-borne water for their water needs as nearby streams and wells provide the main

sources of water used by the people. Hence, the low percentage (0.04%) recorded for this item of expenditure too.

The patterns for cash expenditure in the savanna deviate from those observed in the forest. Education, accounting for 18.8%, had the largest share of cash expenditure. This may suggest that respondents are becoming more aware of the need to send their wards to school, having realized the importance of education since their own years of education were the primary school. As a result, respondents complain about the lack of family labor for their farm operations as children who would usually assist on the farms are being sent to school. Savings were lower in the savanna than in the forest, probably because of the large share of cash disbursed as remittances to the extended family.

Household expenditure estimates follow the quarterly trends for the different items of expenditure. In the forest community, food, savings and clothing were prominent in the first, second and fourth quarters while the percentage of budget share to savings was highest in the third quarter. This could be ascribed to the period of harvest, which falls within the third quarter and is capable of increasing farmers' reserves for the subsequent year's production and use. In the savanna, food, education, and ceremonies were dominant in the first quarter; education, food, and ceremonies in the second and fourth quarters; and education, food and clothing in the third quarter. Households in the forest zone recorded a higher spending profile (double that found in the savanna), probably because the large share of income is from cash crops (tree crops and vegetables against food crops only in savannas) and they consume less of their own food production (35% against 88% in the savanna).

Budget shares of commodities and commodity groups. The budget share value allocated to each food category is used to show the importance of the food item in household budgets. There is no major

difference in the patterns of the budget for food expenditure between the two research sites (Table 2). The energy-based food commodities (cereals, roots and tubers, and plantain/banana) occupy the larger share of cash expenditure. Imported rice was the major food among cereals in these rural areas. Protein-based food items (meat and fish, legumes, dairy products) occupy up to 45% of the budget. A high share of the energy-

based food commodities in the total budget is another indication that their own production is not sufficient to meet the family's needs.

The budget spent on root and tuber-based products was small because a large part of harvest for cassava and yam (the major root and tuber crops) is used for home consumption. These crops are processed into rich and diversified food products (Table 3). As expected, cassava-based products (*gari*/

Table 2: Average budget shares of the household (%) on food commodities in the forest and savanna zones.

Food category	Budget share	
	Forest	Savanna
Cereals	28.55	20.43
Roots and tubers	8.78	14.18
Vegetables	3.71	4.62
Meat and fish	28.75	29.57
Fruits	0.66	0.64
Legumes	11.80	12.44
Plantain/banana	0.74	0.69
Dairy Products	4.30	5.06
Fats and oils	5.03	5.66
Bakery	7.68	6.71
Total percentage	100.00	100.00

Source: Data analysis, 2003.

Table 3: Average budget shares of household (%) on root and tuber products in the forest and savanna zones.

Root and tuber product	Budget share	
	Forest (n = 8.78%)	Savanna (n = 14.18%)
<i>Fufu</i>	2.16	0.49
<i>Gari</i> and <i>Eba</i>	41.12	13.54
Boiled yam	20.39	11.28
<i>Amala</i>	14.01	59.59
Pounded yam	5.01	4.87
Cassava flour	8.88	3.53
Cocoyam	8.43	6.70
Total	100.00	100.00

n = total percentage

eba and cassava flour) are important in the forest zone, while yam-based products (boiled yam, *amala*, and pounded yam) are important in the savanna zone. In this zone, yam was ranked as the most nutritious, the most important, and the tastiest crop by more than 90% of respondents in the 1970s (Zuckerman 1979). The current budget for yam-based foods (about 75.7% of the budget for roots and tubers) is an indication of the relative decline of this commodity in the food basket.

Determinants of household demand for root and tuber products in the forest and savanna zones. This section discusses results from the statistical analysis using the AIDS model. For almost all equations, the F values are large and significant at the 1% level or below. Therefore, the models are robust enough to be used in estimating the coefficients of the explanatory variables included in the analysis. The low R² values were observed for some of the AIDS equations. However, the recorded figures appear good for cross-section data as revealed by previous studies (Deaton and Muellbauer, 1980; Savadogo and Brandt, 1995), particularly since the dependent variables represent budget shares. The Durbin-Watson statistic for each equation and each food commodity was computed to test the presence of serial correlation. These results led to the rejection of the hypothesis of serial correlation in most cases. Thus, the data were considered free of autocorrelation. According to Pindyke and Rubinfeld (1998), elasticities computed from cross-section data are generally interpreted as long-run parameters that reflect the adjustment of all variables causing households to be different (Timmer *et al.*, 1983).

Each coefficient in the results from AIDS models represents the effect on the dependent variable of a 1% change in the explanatory variable. However, since the dependent variables are budget shares (i.e., total expenditure on the commodities), the estimated parameters are occasionally very small. Therefore, multiplying the original coefficients by 100 will allow for easy

interpretation (Deaton and Muellbauer, 1980). The coefficients can therefore be read to represent 100 times the effects on budget shares of a 1% change in the independent variables.

Factors determining the demand for root and tuber products. The results of the AIDS model on roots and tubers show that among the demographic characteristics in the forest zone (Table 4), household size recorded a positive and significant relationship on the budget share for *fufu* and pounded yam. This implies that one more household member in the family will increase the budget share of *fufu* by 0.18% and that of pounded yam by 0.21%. A negative and significant effect was obtained for boiled yam, which implies that as the household size increases by 100%, the budget share of boiled yam reduces by 0.57%. This suggests that households in the forest zone prefer pounded yam to boiled yam. The response to education is significant and positive in the *amala* equation while age recorded a negative significant coefficient in the cassava flour equation. Raising the educational level by 100% in the forest will increase the percentage budget share of *amala* by 0.68%, while age tends to reduce the budget share allocated to cassava flour. Thus, demographic variables such as household size, age, and education are very important in determining the household budget allocation to roots and tubers in the forest ecology. Surprisingly, none of the demographic variables was statistically significant in determining the budget share of roots and tuber products in the savanna zone (Table 5). No clear explanation could be found for these results.

In the forest ecology, the coefficients for root and tuber products show that *gari/eba* has an own-uncompensated price of -0.3050, meaning that an increase of *gari/eba* price by 100% would result in the decrease of its budget share by 30.5% (Table 4). To compensate for such a price increase and smaller budget (thus lowered consumption), households would increase the consumption

Table 4: Coefficients of estimates for root and tuber products in the forest zone: results from the AIDS model.

Explanatory variable	Dependent Variable*						
	Gari/ Eba	Cassava flour	Boiled yam	Fufu	Cocoyam	Pounded yam	Amala
Uncompensated price							
Gari/Eba	-0.3050	0.0222	-0.196 ^b	0.0259	0.3060 ^a	0.0575 ^c	0.0890
Cassava Flour	0.0147	0.1140	0.163 ^c	0.0463	-0.0721	0.0110	-0.2770 ^a
Boiled yam	-0.0750	0.0190	0.0542 ^b	-0.0047	0.0105	0.0009	-0.0049
Fufu	-0.0202	0.0078	-0.0869	0.0473 ^c	-0.0014	0.0243	0.0290
Cocoyam	-0.0059	0.0326	0.0888	-0.0027	-0.0238	-0.0103	-0.0788
Pounded yam	0.174	-0.0358	-0.243	-0.0720	0.1470	0.1750 ^b	0.1490
Amala	0.0071	0.0360	-0.0509	-0.0001	0.0359	0.0229	-0.0508
Income							
Expenditure	-0.2320	-0.0414	0.140 ^a	-0.0071	0.0589 ^a	0.0272 ^a	0.0547 ^b
Demographic Characteristics							
Household size	0.0024	-0.0015	-0.0057 ^c	0.0018 ^c	-0.0003	0.0021 ^c	0.0010
Age	-0.0012	-0.00001 ^b	0.0004	-0.0005	-0.0009	0.0008	0.0013
Education	-0.0011	-0.0005	-0.0056	-0.0017	0.0009	0.0012	0.0068 ^c
Intercept	2.418	-0.4060	0.358	-0.141	-0.8130	-0.8620 ^a	0.4470
F	18.505	3.025	7.964	1.176	4.5820 ^a	3.190 ^a	1.870 ^b
R ²	64.7	23.1	44.1	10.4	31.2	24.0	15.6

*Dependent variables are represented as budget shares

^a, ^b, ^c indicates significance at p < 0.01, p < 0.05, and p < 0.10 respectively.

Source: Data analysis, 2003.

of cocoyam by 30.6% and pounded yam by 5.8% as shown by the magnitude of their respective cross-price coefficients. The positive significant cross-price coefficients of cassava flour and boiled yam, *gari/eba* and pounded yam, as well as *gari/eba* and cocoyam suggest that they are likely to be substitute goods. Complementarity exists between products with a negative significant coefficient such as *gari/eba* and boiled yam and cassava flour and *amala*. The negative income coefficients of *gari/eba*, cassava flour, and “fufu” indicate that the commodities have less than one income elasticity, while the significantly positive income coefficients of boiled yam, cocoyam, pounded yam, and *amala* show that the commodities are highly responsive to household income, with an income elasticity greater than one.

In the savanna ecology, statistically

significant, own-uncompensated price coefficients were recorded for *gari/eba*, boiled yam, and *amala* (Table 5). The positive and significant cross-uncompensated price effects between cocoyam and cassava flour, *fufu* and pounded yam, and *amala* and pounded yam suggest that these commodities are likely substitutes, while complementarity exists between *fufu* and boiled yam, *gari/eba* and *fufu*, as well as between boiled yam and *amala*. Except for the budget share of *amala* in the roots and tuber food category, all the statistically significant income coefficients recorded a negative sign and suggest less than one income elasticity.

Estimates of own and cross-price elasticities for root and tuber products. The own price for each commodity of root and tuber products can be read diagonally from the

Table 5: Coefficient of estimates for roots and tuber products in the savanna zone: results from the AIDS model.

Explanatory variable	Dependent variable ^a						
	Gari/ Eba	Cassava flour	Boiled yam	<i>Fufu</i>	Cocoyam	Pounded yam	<i>Amala</i>
Uncompensated price							
<i>Gari/Eba</i>	-0.034 ^c	-0.0011	0.0307	-0.0072 ^c	0.0538 ^a	-0.0168	-0.0251
Cassava flour	-0.159	0.047	0.118	-0.0075	-0.0830	0.0368	0.0454
Boiled yam	0.0082	-0.0031	0.067 ^a	-0.0015	-0.0038	0.00138	-0.0677 ^a
<i>Fufu</i>	-0.317	0.168	-1.139 ^b	0.00932	0.218	0.640 ^c	0.426
Cocoyam	-0.024	0.019 ^b	0.000097	-0.00112	0.0112	0.0094	-0.0147
Pounded yam	0.029	-0.014	0.0217	0.00139	-0.0196	0.0103	-0.0288
<i>Amala</i>	0.043	0.0137	0.178 ^a	0.00799	-0.0146	0.102 ^a	-0.315 ^a
<i>Income</i>							
Expenditure	-0.055 ^b	-0.0122	-0.221 ^a	0.0043	-0.0787 ^a	-0.155 ^a	0.517 ^a
Demographic characteristics							
Household size	0.00025	-0.00095	0.00034	-0.000129	-0.00197	0.00119	0.00127
Age	-0.00074	0.00009	-0.000024	0.000145	0.00074	-0.00042	0.000216
Education	-0.00056	-0.00011	0.000867	0.000265	-0.00031	-0.00060	0.000431
Intercept	1.705	-0.595	2.499	0.0496	-0.0635	-1.594	-0.960
F	1.604***	1.109	8.054 ^a	0.955	3.525 ^a	10.218	75.378 ^a
R ²	13.1	9.4	43.1	8.2	24.9	49.0 ^a	87.6

^aDependent variables are represented as budget shares

^{a, b, c} indicates significance at $p < 0.01$, $p < 0.05$, and $p < 0.10$ respectively.

elasticities matrix in Tables 6 and 7 for the forest and for the savanna zones, respectively.

In the forest zone, the own (direct) price elasticity for *gari/eba*, *amala*, pounded yam, cocoyam, and *fufu* are large in absolute value (i.e., > 1). This shows that the demand for these commodities is price elastic, while the demand for boiled yam (-0.874) and cassava flour (-0.913) are price inelastic. In the savanna ecology, only the demand for *gari/eba* (-1.1962) and *amala* (-2.0455) were price elastic while the demand for other commodities was inelastic.

Except for *fufu*, all other food commodities had the expected negative own price signs in the two zones. For example in the forest zone, a 1% price decrease will induce households to increase their consumption of *gari/eba* (+1.5%), *amala* (+1.4%), pounded yam (+1.9%) and cocoyam (+1.3%). The positive

coefficients of *fufu* may be due to the insignificant level of its consumption in the two ecologies. A similar positive coefficient (0.3465) was obtained for cassava flour in the savanna zone. This could be due to the small proportion of income spent on this product since most cassava flour is obtained from own farm production.

The cross-price elasticities for some of the commodities in the zones are positive while others are negative (reading down in Tables 6 and 7). The positive cross-price elasticities of demand between *gari/eba* and *amala* (0.5434) in the forest and between *gari/eba* and boiled yam (0.8822) in the savanna, for example, suggest that these commodities are substitutes. This implies that an increase in the price of *amala* will lead to an increase in the demand for *gari/eba*. Similar relationships were recorded for *gari/eba* and *fufu*, *gari/eba*

Table 6: Own-price, cross-price and expenditure elasticity estimates for root and tuber products in the forest zone: results from the AIDS model.

Commodity	Price elasticity						
	<i>Gari/Eba</i>	Boiled yam	<i>Amala</i> yam	Pounded flour	Cassava	Cocoyam	<i>Fufu</i>
<i>Gari/Eba</i>	-1.509	0.3156	0.5153	0.9211	0.5337	0.4840	0.4489
Boiled yam	-1.1225	-0.874	-0.4098	-1.353	0.6408	0.2763	-0.0174
<i>Amala</i>	0.5434	-0.126	-1.4167	-0.9710	-2.065	-0.653	0.1157
Pounded yam	-0.2350	-0.1074	0.3283	-1.870	0.0926	-0.3290	0.3559
Cassava flour	0.142	0.105	0.2969	-0.510	-0.913	0.2587	-0.0202
Cocoyam	3.4674	-0.0378	-0.0378	1.5814	-1.017	-1.3421	1.6986
<i>Fufu</i>	1.144	-0.299	-0.083	-3.47	2.106	-0.205	1.2382
Expenditure elasticity	0.4489	1.68	1.8676	-2.196	1.9149	0.6534	-0.1781

Table 7: Own-price, cross-price and expenditure elasticity estimates for root and tuber products per household in the savanna zone: results from the AIDS model.

Commodity	Price elasticity						
	<i>Gari/Eba</i>	Boiled yam	<i>Amala</i>	Pounded yam	Cassava flour	Cocoyam	<i>Fufu</i>
<i>Gari/Eba</i>	-1.1962	-0.4261	0.1794	1.4102	0.2354	0.0830	-0.022
Boiled yam	0.8822	-0.6289	2.1834	0.8027	1.6534	0.6118	-7.797
<i>Amala</i>	-0.3121	-0.3836	-2.0455	-0.3183	-0.1938	0.2947	0.1428
Pounded yam	0.6536	-0.3958	3.1031	-0.3134	1.7588	1.1938	14.1959
Cassava flour	0.0768	0.0199	0.4972	-0.2897	0.3465	0.6478	4.8807
Cocoyam	0.4364	-0.4259	-0.5875	-0.6624	-1.6115	-0.9013	2.8945
<i>Fufu</i>	-1.8219	-0.6091	1.4100	0.0057	-1.8857	-0.5283	0.9787
Expenditure elasticity	0.5944	-0.9523	1.8676	-2.196	1.9149	1.6534	-0.1781

and cassava flour, and *gari/eba* and cocoyam. The degree of substitutability between most of the commodities was not strong (i.e., with coefficients < 1). Negative cross-price elasticities were obtained for products that are complements such as *gari/eba* and pounded yam (-0.2350) in the forest or *gari/eba* and *amala* (-0.3121) in the savanna. Thus, an increase in the price of pounded yam, for example, will lead to a decrease in the demand for *gari/eba* in the forest zone. The degree of complementarity was found strong between pounded yam and *fufu* (-3.47) in the forest and between *fufu* and boiled yam (-7.797) in the savanna.

Expenditure elasticity estimates for roots and tuber products. In the forest zone, the expenditure elasticities for root and tuber products (Table 6) show that when income increases, households will consume relatively more cassava flour (1.9149), *amala* (1.8676) and boiled yam (1.68). On the other hand, households will consume relatively less *gari/eba* (0.4489) and cocoyam (0.6534). This implies that when income increases by 10%, expenditure on *gari/eba* increases by 4.49%. So, *gari/eba* is an income-inelastic food item and a necessity for the households. The negative expenditure elasticity estimate for pounded yam (-2.196) and *fufu* (-0.1781) imply

that increases in household income will lead to decreases in the consumption of these commodities.

In the savanna zone, cassava flour, *amala* and cocoyam recorded positive estimates (Table 7). Thus, households in the savanna will consume relatively more of these commodities as income increases. All the other products recorded negative expenditure elasticities.

Conclusion and Policy implications

This paper examined the expenditure patterns of households in two rural communities of the forest and savanna zones in southwestern Nigeria. Despite the fact that farmers dispose a high proportion of harvest for home consumption, expenditures on food items were found to be relatively high. This is another indication of poverty with food shortages in the study area. The above facts on poverty re-emphasize the needs for the development of strategies, programs, and projects targeted to poverty alleviation and wealth creation in sub-Saharan Africa. It was found that farmers spend their financial capital in order to attend to many household needs, including social obligations. Successful development programs must embrace the entire rural space rather than limiting their intervention to agricultural production only.

Roots and tubers represent an important component of a food security strategy. In the study area, they are processed into many products and consumed in different forms: *gari/eba*, cassava flour, *fufu*, boiled yam, *amala*, pounded yam, and raw cocoyam. These products were already identified 30 years ago in the 1970s (Zuckerman, 1979). Therefore, no progress seems to have been made on linking farmers to markets despite increases observed for the study villages in community assets such the building of new roads, banks, daily market places, churches, light street, etc. The availability of market infrastructure alone is not a sufficient condition of igniting a commercial farming. Infrastructure needs to be complemented with

clear market development oriented strategies for subsistence farmers to fully enter into commercial farming.

There is a contrast in the sources and level of income between the study villages. A difference was also observed in the food basket between the two communities: cassava-based products are important in the forest zone, while yam-based products are important in the savanna zone. Therefore, ecological (regional) differences must be taken into consideration in the design of interventions to promote the utilization and consumption of root and tubers in Nigeria. The concept of development domains could be used in developing and targeting research-for-development strategies for these commodities.

Demographic factors, such as household size and age, were found to be significant factors for consideration in household budget allocation decisions on root and tuber products in the forest zone. None of the demographic factors was found significant for the savanna zone.

The analysis of own-price and cross-price elasticities in the two agroecologies revealed that, except for *fufu*, roots and tubers products conform to a priori expectations. The expenditure (as a proxy of income) elasticity indicated responsiveness to income for boiled yam, *amala*, pounded yam, cassava flour in the forest zone and *amala*, pounded yam, cassava flour, and cocoyam in the savanna zone. Therefore, prices and income appear to have a major effect on households' budget allocation to roots and tubers in southwestern Nigeria. Thus, exploiting market opportunities for root and tuber products through new product development and formulating conducive policies that will enhance stakeholders' (farmers, processors, and traders) production, processing, and utilization of these crops will immensely assist in improving food security within the country. However, root and tuber-based products respond differently to market forces as shown in the differences for own, cross, and income elasticity of various products, including in

remote rural areas. Therefore, exploiting market opportunities must be product specific and not commodity specific, even for roots and tubers. Extension education to farmers on the use of appropriate land management practices is still required to overcome constraints to low productivity of roots and tuber crops in farmers' fields.

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A review of post-harvest activities for cassava in Tanzania

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Abstract. Post-harvest problems affecting cassava in Tanzania are high losses during marketing of fresh cassava and rudimentary processing technology. A needs assessment study identified reduction in income from post harvest losses as a major problem facing stakeholders involved in production and marketing of fresh cassava roots from rural areas to urban markets. The most suitable intervention identified to address the problem of fresh cassava root storage was adoption of the modified low-cost fresh cassava root storage technology originally developed by the Centro Internacional de Agricultura Tropical (CIAT) in Columbia and Natural Resources Institute (NRI) of U.K. The technology was tested in several villages in Coast region and two urban markets in Dar es Salaam, after which a flexible dissemination strategy was developed and applied to other villages between 1996 and 1998. Processing of cassava and other root crops into more storable forms offers an opportunity to overcome perishability of the fresh produce. Processing of cassava also provides a means of adding value to the crop. Cassava processing methods in Tanzania are varied especially in the four main cassava growing zones. The products obtained are always moulded, contaminated with sand and may contain high levels of cyanogens. This is because cassava processing methods are simple and do not result in tissue disintegration but leaves behind high levels of cyanogens in intact peeled whole or split roots. The most suitable processing method adopted in these zones since 1996 is chipping or grating of fresh cassava roots before

obtaining flour. The flour is an intermediate product for various bakery, industrial and pharmaceutical products. Efforts to disseminate the technology were initiated and some villages in eastern and lake zones were involved.

Introduction

Cassava is a basic staple for hundreds of millions of people in the tropical and sub-tropical belts as well as being a feedstock for numerous industrial applications, including food, feed and starch (IFAD/FAO, 2001). It is a source of food security not because it can be grown on less productive land but because it is a source of income for producers. It is predicted that cassava will spur rural industrial development and raise incomes for producers, processors and traders in the near future. Cassava contributes to the food security status of the producing and consuming households. Urbanization in cassava-producing countries represents an opportunity for producers to produce cassava for a larger consuming population. This means that cassava markets for fresh roots and processed products can grow if the products are convenient and are in a more desirable form. Cassava products include flour, animal feeds, alcohol, starches for sizing paper and textiles, sweeteners, prepared foods and biodegradable products. The products are derived from a number of forms of cassava ranging from fresh leaves and roots to modified cassava starch.

Post-harvest handling of cassava begins the moment it is harvested. It ranges from

simple uprooting/ lifting of the roots from the ground, ferrying them to the house for immediate consumption after cooking or subjected to sophisticated preparatory methods of processing into high quality food products. Processing of cassava and other root crops into more storable forms offers an opportunity to overcome perishability of the fresh produce resulting into safe, palatable and storable products (Lancaster *et al.*, 1982). It provides a means of adding value to the crop. For fresh cassava, processing is a means of stabilizing them to improve storage, increase shelf life and provide income generation opportunities especially for women in the rural areas (CPHP, 2000). Processing simplifies transportation of cassava products to the urban markets due to reduced water content and waste materials of the fresh roots.

Cassava processing and post harvest handling in Tanzania is still rudimentary. The methods employed are simple ones and are not efficient in removing cyanogens to safe levels (Mlingi, 1995). The processing methods can be categorized into:

- i) Direct sun drying of peeled roots or root pieces for some days on platforms, roof tops or on some rocks in the field to obtain a product called *makopa*. This is the popular method practised in most cassava growing areas.
- ii) Soaking in water for several days. During this period the roots undergo fermentation by submerging peeled or unpeeled roots. Subsequently, the product is sun dried.
- iii) Heaping involves air or solid-state fermentation of peeled roots/ root pieces for some days.

Products obtained by the above mentioned methods are later pounded or milled into flour for making stiff porridge (*ugali*). The *makopa* product can alternatively be soaked in water and boiled in which oil, salt, tomatoes and onions are added and consumed. *Makopa* or the flour is used for brewing purposes in some communities.

Post-harvest research activities on cassava in Tanzania. National efforts to improve cassava post harvest handling started actively in early 1980s (Msabaha *et al.*, 1986; Shao *et al.*, 1988). Targets put forward on cassava post harvest by various research institutions in Tanzania are:

- Improvement of local processing and storage facilities for cassava,
- Conducting surveys on consumer demands for cassava,
- Establishing the effects of cyanogen residues in processed cassava products and
- Conducting socio-economic evaluations of improved cassava processing and storage.

Several activities were undertaken to achieve some of the above targets. Notable outputs from such activities were documentation of existing traditional cassava processing methods, determination of cyanogen levels in cassava products and health effects associated with consumption of insufficiently processed cassava (Mlingi, 1995). In all these activities no attention was given to handling of fresh cassava roots and their marketing.

From the 1990's attention on cassava post harvest research focused on four major areas namely:

- i) Storage and extension of shelf-life of fresh cassava roots,
- ii) Cassava product diversification in rural and urban areas,
- iii) Improvement of cassava processing methods by introduction of cassava processing equipment such as graters, chippers, presses, etc.
- iv) Identification of post harvest storage pests and diseases of cassava.

Low-cost fresh cassava root storage technology. A needs assessment study carried out in Dar es Salaam identified that reduction in income from post-harvest losses was a major problem facing stakeholders

involved in marketing of fresh cassava roots from rural to urban markets (Ndunguru *et al.*, 1994). This was because of the perishability of cassava roots. The most suitable intervention identified to address the problem of the fresh cassava root storage was adoption of the modified low-cost fresh cassava root storage technology originally developed by the Centro Internacional de Agricultura Tropical (CIAT) in Columbia and Natural Resources Institute (NRI) of U.K. They developed a simple conservation strategy based on cassava root storage in polypropylene bags combined with water or chemical treatment to control secondary microbial (fungal) rotting. Storage of up to one month was achieved and this permitted the provision of fresh, high quality product to consumers.

The original CIAT/NRI technology involved harvesting and selecting high quality, relatively undamaged roots from low cyanide cassava varieties. The roots are washed or cleaned and then dipped or sprayed with a fungicide, thiabendazole which is widely used as a post-harvest treatment for banana and potato. The drained roots are then placed in polypropylene bags that are sealed. The respiration of the roots within the bag causes the relative humidity (RH) of the enclosed atmosphere to rise. The high RH in combination with a temporary holding of the bagged roots at high temperature causes root curing which promotes an extension of shelf life of the roots (CIAT, 1989).

The technology adopted in Tanzania was validated in Ghana by NRI in collaboration with the Ministry of Agriculture and Food to test its suitability in Ghana. In Tanzania it was tested in several villages in Coast region and two urban markets in Dar es Salaam by TFNC and NRI, after which a flexible dissemination strategy was developed and applied to other villages. In a case study carried out at the same time, it was shown that successful adoption of the technology would improve the quality of cassava reaching the urban consumers and contribute to poverty alleviation by improving the income

generating potential of marketing of fresh cassava.

The technology involves a series of steps which link together to create optimal conditions for storage of cassava roots under field conditions. The steps include:

- Harvesting of cassava roots carefully with roots intact on the stem,
- Removing roots from the stem taking care to avoid wounding the roots,
- Separating damaged and undamaged roots,
- Using a sharp knife to make smooth cuts in damaged surfaces and allowing cut surfaces to dry before dipping roots in water,
- Pouring water into a large container and dipping roots in the water for about one minute,
- Putting wet roots into sacks,
- Tying sacks with string,
- Placing sacks on a platform of logs in the shade,
- Wrapping sacks with plastic sheets or sheets made from old sacks sewn together.

Dipping sound roots in water and maintaining them at high humidity for several days in the shade was shown to extend the shelf life of fresh cassava roots for seven to ten days without the necessity of using the fungicide (Ndunguru *et al.*, 1998). Before adoption of this technology, three storage trials were conducted to demonstrate the feasibility and potential of the cassava storage technology. One was on-station at TFNC to demonstrate the ability of high humidity and fungicide (thiabendazole) treatments to prolong the storage of fresh cassava roots for periods of one to two weeks, respectively. Later with the local wholesale agents, two further market-based demonstrations were carried out to show the effectiveness of different elements of the storage technology. A five-day investigation highlighted the contribution of shade to minimising the rate of cassava deterioration. Finally cassava traders were

introduced to the concept of creating a cassava clamp using polypropylene sheets to conserve sacks of cassava in the open market.

Validation exercises demonstrated that low cost fresh cassava root storage technology has the technical and economic potential to alleviate post-harvest losses associated with marketing of fresh cassava and improve the incomes of those involved in the cassava marketing system (Ndunguru *et al.*, 1998). This was shown in an economic study which demonstrated that as a consequence of using the technology, profits could be increased by as much as 16% for certain participants in the marketing chain (Mashamba, 1997). Key stakeholders were genuinely interested in adoption of the technology and were willing to cooperate and spend their own funds to promote the uptake of the technology.

Processing of high quality cassava flour.

Adoption of low-cost fresh cassava root storage technology made it possible getting fresh roots to the urban consumers. The technology could also assure urban processors a good supply of fresh roots suitable for processing into high quality cassava flour for bakery and industrial purposes. This is because the increase in population and the trend in urbanization make it necessary to diversify cassava products and to maintain their appeal to consumers. Efforts to partially substitute wheat flour with indigenous crops such as cassava and yams have been made to minimize the expensive wheat imports. Studies done at the International Institute of Tropical Agriculture, Ibadan Nigeria and Katholieke Universiteit Leuven, Belgium demonstrated the possibility of baking bread with cassava flour using the same ingredients used in baking the conventional wheat bread. A method for producing high quality cassava flour suitable for baking was developed and this was adopted in Tanzania in 1993.

The method involves peeling the roots, washing and chipping in a manually operated chipper and sun drying on a black plastic mat.

The loading density recommended is 2 kg/m² while the temperature at the mat surface could vary from 26.8 to 49.1°C and the drying time range from 4 to 8 hours. The dried chips are milled and sieved through a 25 mm mesh size sieve. The flour obtained has moisture content of 8 – 12% and should be stored in air tight containers. With this kind of flour, a proportion of 20% cassava flour could be added to 80% wheat flour to make composite breads indistinguishable from 100% wheat breads (Omoaka, 1993).

The first training of baking cassava bread and other products such as biscuits, bread buns, cakes, chinchin, cookies, doughnuts and croquettes was conducted at TFNC where a number of staff were involved. The trained staff alternatively trained 15 women groups in Dar es Salaam and Coast region who in turn trained other women in their areas. All the baked products were subjected to sensory evaluation at various stages of product development. The degree of liking or disliking of the products by a cross-section of people from a wide range of income groups showed that cassava cake was most preferred, probably because of its sweet taste while the cassava starch bread was highly preferred. Comments from the taste panelists indicated that cassava-soy bread could be preferred when used with stews and sauces just like any other starchy staple food.

Cassava flour product diversification for income generation.

In needs assessment studies in Lake zone (Thro, 1994; Rwiza *et al.*, 1995; Ndunguru *et al.*, 1998) women processors and market vendors expressed interest in increasing the range of cassava products. In collaboration with TFNC and ARI – Ukiriguru Mwanza, the Natural Resources Institute addressed this request under a Regional Technology Transfer Project on non-grain starch staples funded by the Department for International Development (DFID) of U.K. Various products such as doughnuts, chin-chin, croquettes, cakes and biscuits were prepared and tested for acceptability. This was carried out hand in

hand with training of 75 individuals beside 138 trainers of others who were supported by Client Oriented Research (COR, 1998) programme for Lake zone and Southern Africa Root crops Research Network (SARRNET). Follow up activities on dissemination and uptake showed that there was demand for three products especially cassava doughnuts, chin-chin and cakes which warranted a dissemination phase during which several workshops were organized (Kapinga *et al.*, 1998). To ensure sustainability of the diversification of cassava products, the dissemination package in Lake zone focused mainly on women, community groups and farmer research groups. The wide dissemination phase in the zone advocated networking and collaboration with other stakeholders especially NGOs, rural community based organizations, government projects and international agencies. About 509 women representing 82 community groups were trained to serve as trainers for others. In the follow up of technology transfer it was learnt that at least every one person trained, passed the knowledge to eight more people.

Technology and equipment for processing high quality cassava chips/flour.

Technological package on the diversified use of cassava flour through product development went along with improved techniques on processing of high quality cassava flour. Chipping equipment address the constraint of drying during cassava processing (Van Oirschot *et al.*, 2001). The chipping equipment are either manually operated or motorized. Manual chippers on an average cost US \$ 125 while motorised chippers cost around US \$ 500. The manual chipper can on an average chip 69 kg/hour while the motorised one can chip 500kg/hour. The manual chippers were validated and many improvements made. These included stable structure, effective blades, adjustable blades to minimise gaps between blade and the feeder (Ngendello *et al.*, 2001).

In Lake zone different types of hand-operated chippers, graters and presses had earlier on been tested with farmers but were rejected because they were laborious. Other improved models by IITA/ESARC in Kampala Uganda were introduced and tested by 250 farmers in four districts. The equipment was highly accepted by farmers especially community groups. The quality of cassava flour obtained by these machines was compared to that processed by traditional methods. The cassava flour obtained was sold at Tshs. 250 compared to the price of Tshs. 80 – 90 normally paid for traditionally processed cassava flour. Farmers indicated the need to acquire the cassava processing equipment through credit systems (COR, 1998).

In Southern Tanzania, studies on rapid processing of cassava from bitter varieties were carried out by TFNC in collaboration with Natural Resources Institute of U.K. The technology was introduced in four pilot villages in Masasi and Newala districts using manually operated graters. On-station cassava processing trial to compare the efficiency of cyanogens removal in the traditional rapid processing by pounding roots and grating showed that two options were suitable. One option was grating of cassava followed by incubation for three hours (resting the grated mash in the shade) followed by wasting roasted. The second was grating, followed by fermentation over night and then sun drying or roasting. These two options could reduce the level of cyanogens in fresh cassava from an average of 562 ± 300 mg HCN equivalent/kg dry weight to 3.9 ± 7.4 and 5.3 ± 4.9 mg HCN equiv/kg dry weight respectively. The cassava flour obtained by these methods was very safe and acceptable for human consumption and marketing. Note that the permitted level of cyanogens in cassava flour proposed by FAO/WHO in 1991 is 10 mg HCN equiv/kg dry weight.

Pilot processing of high quality cassava flour for biscuit production. Pilot processing of high quality cassava flour for biscuit

production in Dar es Salaam was carried out by TFNC in collaboration with SARRNET office in Dar es Salaam and the Root and Tuber programme of Sugar Research Institute Kibaha. The proportion of 20% cassava flour substituted with 80% wheat flour produced biscuits, which were acceptable to the consumers. The study identified five private bakeries namely Salim Modern Bakery, Souza Plast, New Bakery, Taj-Mahal Confectionery and Thakur which produced biscuits. They were ready to accept substituting wheat flour with cassava if quality cassava flour was made available and technical know how was at hand (Mlingi *et al.*, 1999). Souza Plast bakery was involved in the trial production of cassava biscuits. Similarly the bakeries declared that if significant economic benefits were realized by substituting wheat flour with cassava flour they would adopt the technology. Farmers in the villages surrounding Dar es Salaam were ready to process high quality cassava flour for sale to the bakeries instead of selling fresh cassava roots to the city. Cost benefits calculated on the basis of wheat flour requirement in Tanzania in 1998 showed that the country could save an equivalent of US \$ 1.2 million annually by substituting wheat flour with 20% cassava flour.

Creating markets for small-scale cassava farmers through rural agro-processing of high quality cassava chips/flour. In order to expand production, utilisation and commercialisation of cassava in Tanzania, the SARRNET in collaboration with the National Root and Tuber Programme and TFNC adopted a “linking to markets” approach (Sicco *et al.*, 2003). This approach included:

- Identifying and exploring of new markets for flour, feed, starch and other industrial applications with private partners,
- Identification of viable production areas and partners (peri-urban versus rural) and providing improved production and processing technologies through pilot demonstration sites to rural farmers and link them with identified markets,

- Scaling up assistance of support partners such as NGOs, micro-credit facilitators, traders and development of public-private sector partnerships.

The strategies were also to cater for the need of processing high quality cassava flour to meet the urban demand. For Dar es Salaam city the aim was to guarantee constant supply of high quality cassava flour to feed the bakeries. In responding to this requirement, SARRNET with the collaborating partners decided to set up pilot cassava processing sites in Rufiji district near Dar es Salaam which supplies the bulk of fresh cassava to the city markets. A similar processing site was suggested for Tanga municipality, a town north of Dar es Salaam to supply high quality cassava flour to the consumers in Tanga.

A pilot processing demonstration site was set up at Bungu. In this area, an active farmer group was identified and supplied with a processing equipment. Group members were trained on how to operate the equipment and how to process high quality cassava chips. Some farmers visited potential markets and flour millers in Dar es Salaam. The success of this group sparked off formation of several other groups.

The demand for high quality cassava chips/flour was increased after introduction of a handy 5-kg cassava flour bag which was tested and positively accepted by various sales outlets. The demand resulted in SARRNET supporting the three more farmer groups with processing equipment. At the same time the Rufiji District Council provided small loans to new farmer groups to meet the operational costs. The venture for processing high quality cassava flour looked promising since farmers were getting higher incomes from cassava through reduced transport costs than selling fresh cassava roots.

The sustainability of the farmer/processing groups will however depend on their access to loans. There is therefore a need to link them to micro-credit facilities so that they can continue with their businesses.

Conclusions

The technologies reported here were introduced to only three main cassava growing zones of Tanzania. Although promising, preliminary observations show that diffusion and adoption of the technologies is slow. The task ahead therefore is to devise better ways and strategies for improving the rate of dissemination. This will involve developing cassava products into widely traded commodities so that the market is guaranteed.

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Effect of different storage methods on the shelf-life of fresh sweetpotatoes in Gairo, Tanzania

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Abstract. One of the major constraints to the potential of sweetpotatoes is its perishability commencing soon after harvesting. This is worsened by the lack of suitable storage methods as well as the difficulties to store improved varieties such as SPNO. This study was therefore intended to evaluate the storability of improved sweetpotato varieties and assess the effectiveness of selected storage methods under Tanzanian conditions. Four storage methods were investigated with 50kg of fresh injury free SPNO sweetpotato tubers. The storage methods covered under this study included traditional pit, improved open pit, improved housed pit (*mjinge*) and raised woven structure (*kihenge*). Results obtained from this study showed that housed pit storage (*mjinge*) performed comparatively well whereas the traditional method was the poorest in all attributes. For example, sugar content of sweetpotato stored using *mjinge* method increased significantly ($P<0.05$) from 6.25% to 9.25%. Although *kihenge* method performed well with respect to crude protein that increased from 4.90% to 6.06%, its performance in other attributes was poor. In addition, sweetpotatoes stored by *mjinge* method had good quality attributes of sweetness, starchy mouth feel, smell, colour and general acceptability, scoring between 3.37 and 4.19 in the hedonic scale (0- 5). Sweetpotato stored using this method could be processed for blending with cereals to make composite flours for porridge and also for making fried snacks. Efforts to tap the vast

potential of sweetpotatoes are now underway through joint dissemination with the stakeholders.

Introduction

Sweetpotato (*Ipomoea batatas* L.) is one of the most important household food security crops in Tanzania. The crop complements other food crops and serves to bridge periods of food shortage before the next harvest of maize or other staple crops (Kapinga *et al.*, 1995). It is particularly a suitable food security crop as it produces high yields in a short growing season even under low rainfall (Kone, 1998; MOA, 1996 and Jana, 1982). According to Msabaha (1979) and Kapinga *et al.* (1995), sweetpotato is grown at all altitudes, on all kinds of soils, and in areas where annual rainfall varies between 800 and 1400 mm. In Tanzania, sweetpotato is cultivated by rural families and produced mainly by small-scale farmers. The crop is extensively produced in Shinyanga, Mara, Mwanza, Kagera, Tabora, Morogoro, and Mbeya regions. It is the third most important root and tuber crop in the country (after cassava and round potato), and is grown for home use and for sale (Kapinga *et al.*, 1995). Sweetpotatoes are bargain foods from the standpoint of both nutrition and monetary value. However, despite its potential, sweetpotato production is faced with serious post-harvest constraints, especially storage problems. This arises from lack of suitable

storage methods. The situation is worse for improved varieties, which are high yielding and early maturing but difficult to store. Such newly developed high yielding varieties with poor storability include SPN/O, *Mwanamonde* and *Budagala* (Chilosa, 2000). The traditional pit storage method in which sweetpotato roots are treated with ash has proved to have deterioration effects on storage life and yet farmers use them for local varieties.

In SADC countries like Malawi, researchers have developed storage methods including pit storage in which roots treated with *dambo* sand are stored for a maximum of 3 months (Mbeza, 1996; Akoroda and Teri 1998). However, 3 months is still a relatively short period for storage. Farmers would wish to store their produce for longer periods. The lack of effective storage facilities forces farmers to dispose off their produce immediately after harvest (Akoroda, 1992). During off-season periods, farmers have little to sell and sometimes have little to consume. The practice of disposing off everything during the harvesting season results in a temporary glut in the market leading to low (give away) prices and adversely affecting the economic value of the crop. The main objective of this study was therefore to evaluate the storability of the improved sweetpotato varieties and assess the effectiveness of selected storage methods.

Materials and Methods

The study area. A storage site was identified and prepared at Ihenje village in Gairo division. Gairo division is in the north of Kilosa and experiences droughts with an annual rainfall less than 600 mm. The average annual temperature varies between 18°C on the mountains to 30°C in the river valleys.

Raw materials. Fresh roots of known sweetpotato cultivar (SPN/O), cultivated around Gairo were obtained. All roots were harvested on the same day, sorted, cleaned and stored in different conditions. Injured roots were excluded from the study.

Storage methods. Sweetpotato roots were stored using the traditional pit storage with some modifications. The storage time was set at three months from July to October. The different modifications on the pit storage method are described below:

Traditional pit storage with no other treatments. A pit measuring 1.5 x 1.8 x 1.2 m was prepared. A simple shed was constructed above the pit to protect the roots from direct sunlight. Some 50-kg of fresh sweet-potato roots were packed into the pit on the same day. No chemical or other substance was applied.

Improved open pit. A pit of the same size as described above was dug under shed. A layer of *dambo* sand (about 2 cm thick) was applied on the floor before packing the sweet-potato roots followed by sprinkling little amount of water. *Dambo* sand is inert fine sand from banks of seasonal rivers, and was obtained from a nearby river valley. The same treatment was repeated and subsequent layers of sweetpotato roots, each 12–15 cm thick added. A total of one litre of water and about 5 kg of *dambo* sand was applied per pit. The last layer of roots was covered with a 2-cm layer of *dambo* sand.

Improved housed pit (Mjinge). The design and size of the pit under *Mjinge* storage was similar to the one used for the improved open pit. The only difference in this design was addition of a small hut above it. The hut, measuring 1.8 x 1.8 x 1.5 m was smeared (plastered) with mud leaving a small door and some opening close to the roof for ventilation. Sweetpotatoes were stored in layers separated by a 2 cm thick layer of *dambo* sand. A small amount of water (about 1 litre) was sprinkled to prevent dessication.

Kihenge Storage. The *kihenge* (a simple raised and roofed woven but unsmeared hut) was used. Sweetpotato roots were packed in a *Kihenge* and left for 3 months. No other treatment was applied.

Chemical analysis. This was done using AOAC(1995) official methods of analysis for moisture, crude protein, ash and fat. Vitamin C was determined by 2,6-dichlorophenol indophenol method and sugar by Lane and Eynon method. Sensory evaluation was done using a 5 point hedonic scale where 1=very poor and 5=very good. The data was subjected to Analysis of Variance and means separated by LSD (Steel and Torrie, 1980).

Results and Discussion

Changes in physical characteristics. *Dambo* sand encouraged sprouting of tubers during storage, causing significantly ($P<0.05$) higher number of roots sprouting. This finding confirms reports by Sandifolo *et al.* (1997), that *dambo* sand provides good media (nutrients) for growth. The *mjinge* storage method also encouraged sprouting of roots. This was due to in addition to *dambo* sand, the relatively higher moisture content that was maintained in the shelter. There were significant ($P<0.05$) differences in number of roots sprouted between the pit storage and *kihenge* storage treatments and no significant difference between the *kihenge* storage and *mjinge* was found. The major cause of losses was rotting and insects damage. Although sprouting was evident, it did not affect the perceived sugar content and the general acceptability of boiled roots (Table 1).

In their study, Sandifolo *et al.* (1997) had shown that storage methods (*Mjinge* storage, improved open pit storage treated with *dambo* sand and traditional pit storage) differed

significantly ($P<0.001$) in terms of preserving quality. However, results of the present study show no significant ($P>0.05$) difference between *mjinge* storage and improved open pit storage treated with *dambo* sand, while the traditional pit storage and *kihenge* storage methods differed significantly ($P<0.05$). The *mjinge* storage method was superior in preserving the produce quality followed by the improved open pit storage treated with *dambo* sand and *kihenge* storage, respectively. The number of rotten roots was highest in the traditional pit storage. The number of clean (undamaged) sweetpotato roots was still high in *mjinge* storage and improved open pit storage treated with *dambo* sand respectively. The latter findings are in agreement with the experiment conducted by Sandifolo *et al.* (1997).

Chemical analyses. Results of chemical analyses of crude protein, fat, ash, dry matter, sugar and vitamin C are shown in Table 2. The storage methods differed significantly ($P<0.05$) in preserving the proteins. An increase in protein content was observed for *kihenge* stored sweetpotatoes and a slight decrease in the improved open pit treated with *dambo* sand and *mjinge* storage methods. It is likely that the reason behind the decrease in protein content with improved pit with *dambo* sand and *mjinge* storage methods was due to loss in nitrogen during storage as suggested by Bauman *et al.* (1990).

The results of this study (Table 2) show a significant ($P<0.05$) difference in crude fat between *kihenge* storage and the *mjinge* and

Table 1: Number of roots sprouted, rotten, wilted and weight loss after 3 months storage by different storage method.

Storage method	Number of roots showing signs of sprouting	No. of rotten roots	No. of wilted roots	Weight loss (kg)	No. of infested roots
Traditional pit storage	1.500 ^c	166 ^a	0.5 ^b	48.0 ^a	123.0 ^b
Improved open pit	178.5 ^a	5.5 ^c	1.0 ^b	13.0 ^c	6.0 ^c
Improved housed pit (<i>Mjinge</i>)	183.0 ^a	4 ^c	1.5 ^b	15.5 ^c	8.0 ^c
<i>Kihenge</i>	39.0 ^b	3.8 ^b	5.3 ^a	31.5 ^b	49.5 ^a

² Means in the same column followed by different superscript letters differ significantly ($p<0.05$).

Table 2: Chemical composition of sweetpotato before and after 3 months storage.

	Crude protein (%)	Ether extract (%)	Ash(%)	DryMatter (%)	Sugar (%)	Vitamin C (%)
Before storage						
	4.895 ^c	0.874 ^b	2.710 ^a	91.13 ^b	6.250 ^a	4.005 ^c
After storage						
Traditional pit storage	0.003 ^a	0.017 ^a	0.24 ^a	3.03 ^a	0.010 ^a	0.001 ^a
Improved open pit	4.180 ^b	0.6975 ^b	3.060 ^b	91.940 ^b	10.25 ^c	1.66 ^b
Improved housed pit (<i>Mjinge</i>)	4.680 ^b	0.7095 ^b	3.290 ^b	92.410 ^b	9.25 ^c	1.93 ^b
<i>Kihenge</i>	6.060 ^c	0.8850 ^c	3.330 ^b	92.313 ^b	6.50 ^b	1.25 ^b

² Means in the same column followed by different superscript letters differ significantly ($p < 0.05$).

improved open pit storage treated with *dambo* sand. There was no significant difference between *mjinge* storage and pit treated with *dambo* sand. The *kihenge* storage revealed a high superiority in storage in terms of the crude fat preserved.

In this study, ash content was significantly ($P < 0.05$) higher in all storage methods, except in the traditional pit storage (Table 2), which had lowest ash content compared to fresh potatoes. It was also observed that the ash content was not significantly ($P > 0.05$) different between the *mjinge* and *kihenge* storage methods.

There was a significant ($P < 0.05$) increase in sugar content in all methods except in the traditional pit (Table 2). These results support the work by Morrison *et al.* (1993) that during storage α - and β -amylase activities increase. Also, Lambou (1958) reported increases in sucrose, glucose and fructose contents due to hydrolysis of starch. In this study (Table 2), the amount of dry matter was not significantly ($P > 0.05$) different from the fresh potato roots and the roots stored under *mjinge* and *kihenge* methods. The traditional pit resulted in highly significant ($P < 0.05$) reduction in dry matter. The level of vitamin C decreased significantly ($P < 0.05$) with storage (Table 2). The decrease in this vitamin could have been influenced by the change in the storage temperature, which was fluctuating during the storage period.

Acceptability of stored sweetpotato. Results of sensory evaluation are shown in Table 3. Except for the traditional pit storage method the rest of the storage methods did not significantly affect acceptability of the sweetpotatoes. Sweetpotatoes stored in traditional pit storage were heavily infested, damaged and rotten. *mjinge* storage method produced sweetpotatoes that were significantly ($P < 0.05$) more acceptable. This finding confirms the claims by Mbeza *et al.* (1986) that *mjinge* is suitable in preserving sweetpotatoes and that this method can store sweetpotato for up to 8 months without spoilage. *Mjinge* treatment produced sweetpotatoes that were significantly ($P < 0.05$) sweeter than the rest. The *mjinge* storage method produced the sweetest sweetpotatoes while the improved open pit treated with *dambo* sand and *kihenge* storage showed no significant ($P > 0.05$) difference in sweetness when boiled. The uncooked sweetpotatoes revealed a highly significant ($P < 0.05$) difference in sweetness among the storage methods. The sweetpotatoes from *mjinge* storage method were sweetest while those from *kihenge* and the traditional pit storage methods were the least sweet. There was no significant ($P > 0.05$) difference in starch levels between improved open pit storage treated with *dambo* sand, *mjinge* and *kihenge* storage methods, despite the sweetness differences observed.

Table 3: Mean scores of sensory attributes for sweetpotatoes stored by different methods^{1,2}

Storage method	Sweetness		Starchy mouth-feel		Smell		Colour		General acceptability
	raw	boiled	raw	boiled	raw	boiled	raw	boiled	
Traditional pit storage	2.05 ^a	1.76 ^a	2.44 ^a	2.07 ^a	2.02 ^a	2.94 ^a	1.88 ^a	1.98 ^b	2.04 ^a
Improved open pit	3.34 ^b	3.75 ^b	3.63 ^b	3.37 ^b	3.67 ^b	3.42 ^b	3.42 ^b	3.07 ^b	3.22 ^b
Improved housed pit (<i>Mjinge</i>)	4.00 ^c	4.19 ^c	3.71 ^b	2.85 ^b	3.45 ^b	3.37 ^b	3.45 ^b	3.37 ^b	4.14 ^c
Kihenge	2.45 ^a	3.48 ^b	4.15 ^b	3.37 ^b	4.13 ^c	4.15 ^c	4.13 ^c	4.15 ^c	3.41 ^b

¹Entries are mean scores based on a 5-point hedonic scale with: 1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = very good.

² Means in the same column followed by different superscript letters differ significantly ($p < 0.05$).

The smell of sweetpotatoes from the four storage methods were significantly ($P < 0.05$) different from that of fresh sweetpotatoes. This could have been a result of infestation by insects, weevils and microbes. It is also thought to be due to continued degradation of proteins and other biologically active constituents that take place during storage. Sweetpotatoes from *kihenge* storage method had a smell close to that of fresh sweetpotato and thus most accepted. This was probably because there was little degradation of organic compounds in the sweetpotato and little infestation in this method. The sweetpotatoes underwent wilting that concentrated the soluble solids.

Sweetpotatoes store in the *kihenge* treatment were significantly ($P < 0.05$) most appealing in colour. No significant ($P > 0.05$) difference in colour existed between sweetpotatoes stored in improved open pit treated with *dambo* sand and those stored in *mjinge*. The sweetpotatoes stored in traditional pit were the least appealing and had unattractive colour. Sweetpotatoes from the *kihenge* storage method were not significantly ($P > 0.05$) different in colour, compared to fresh sweetpotatoes, thus highlighting the potential of this method of storing fresh sweetpotatoes. All methods of storage resulted in significant ($P < 0.05$) losses of vitamin C.

Conclusions

Results obtained from this study strongly suggest that *mjinge* storage method is a suitable method for storage of fresh sweetpotatoes up to three months. However, this method like the rest, results in substantial losses of vitamin C. The sprouting of roots in storage did not affect their overall acceptability and the chemical composition after storage; actually it increased the sugar content, an attribute that is preferred in the market.

Also, the *mjinge* storage method would be a suitable method, where sweetpotato roots are to be blended with cereals for composite flours to prepare different traditional food like porridges. This is because there is a tendency of an increase in sugar content of sweetpotato stored by this method.

The traditional pit storage was unsuitable for storage of sweetpotato. This confirms our field finding that most people do not store their potatoes using this method. They would rather sell their crop immediately after harvesting, even if the price is very low.

Recommendations

The storage methods investigated in this study need wider dissemination in sweetpotato growing areas. Farmers need to be taught about the potential of *dambo* sand

in sweetpotato storage and its identification. Since *dambo* sand is not readily available, studies on alternative materials of similar characteristics need to be investigated. Efforts to tap the vast potential of sweetpotato in Tanzania need intensification. In the future, handling practices and manipulation of storage environments may be tried out for more effective ways to reduce moisture and nutrient losses.

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Effect of emulsifiers on sensory acceptability of cassava flakes

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Abstract. Reconstituted cassava flakes mash becomes sticky, so emulsifiers are normally added to improve their textural characteristics and sensory quality. Three types of emulsifiers were added to cassava flakes: glyceryl monostearate (monoglyceride), sodium caseinate and skim milk. Sensory scores from 12 judges showed that, the use of glyceryl monostearate (monoglyceride) significantly reduced the stickiness and resulted in a whiter mash. Cassava flakes mash with sodium caseinate and skim milk powder were sticky and dark in colour reducing their sensory acceptability. Pasting characteristics of cassava flour and flakes by the Brabender amylograph indicated that, samples with glyceryl monostearate had low viscosity. This is due to the ability of glyceryl monostearate to reduce starch granules gelatinisation. Starch granules from flakes with sodium caseinate and skim milk powder, gelatinised and burst completely, which resulted into a sticky reconstituted mash. Reconstituted cassava flakes mash with glyceryl monostearate (monoglyceride) was mealy, thus acceptable like freshly cooked cassava mash.

Introduction

Cassava is a high moisture content and bulky crop. The lack of suitable preservation methods makes it very difficult to insure its supply throughout the year (Onayemi and Potter, 1974).

Cassava flakes may provide a convenience food, become a substitute for fresh cassava and stay longer. Walker (1985) defined convenience foods as those products, in a preserved state, whether frozen, dehydrated or canned, which their preparation by the customer, require minimal skills and time to produce an acceptable dietary item.

The idea of production of cassava flakes came from the available substantial information on the production of potato flakes (Wang *et al.*, 1992) and sweetpotato flakes (*Ipomoea batatas*) (Walter and Purcell, 1978). Flakes are a form of dehydrated mash of a particular food. They rehydrate instantly to produce the mash with almost the same textural characteristics or “feel in the mouth” as the mash prepared from the freshly cooked food. Flakes preparation from roots involve, peeling, slicing, pre-cooking, cooking, mashing followed by drying (van Arsdel *et al.*, 1973).

To improve textural characteristics of reconstituted flakes mash, emulsifiers are added. In food products rich in starch, the effect of emulsifiers like saturated monoglycerides is often attributed to their ability to form insoluble complexes with amylose (Hoover and Hadziyev, (1981 b). Proteins are also used as emulsifiers and stabilisers. This is due to their ability to interact with water, small ions and other polymers at the oil/water interface. In that case, compounds like sodium caseinate and skim milk powder are very effective emulsifiers, stabilisers and foaming agents.

Materials and Methods

Cassava flakes were prepared with some emulsifiers to evaluate their effect on sensory quality of reconstituted mash. Roots were pre-cooked at 100°C for 5 minutes with addition of emulsifiers during the mashing process. Cassava mash was dried on a drum drier at the speed of 11.5 r.p.m (4.0 second) and steam pressure 275.8 kNm⁻² (140°C).

Types of emulsifiers used were, stearate monoglyceride, skim milk powder and sodium caseinate. About 2% of the mash's weight of the emulsifiers was used except for stearate monoglyceride where 1.5% was used. The choice of emulsifiers was based on preliminary trials.

Cassava flakes samples were reconstituted with water (1:2). Cooked fresh cassava was used as the reference (standard). Samples were analysed by a sensory panel of 12 judges and the tests were repeated three times. The parameters evaluated were taste colour, stickiness, texture, and general acceptability. Qualitative Descriptive Analysis (QDA), which shows the kind or magnitude of differences between samples was used. A five Point Hedonic scale was used (1= extremely brown, 5 = extremely white) to characterise the different mashers.

Pasting characteristics of cassava flour and flakes. The Pasting properties of cassava flour and flakes with emulsifiers were determined using a Brabender amylograph (Brabender OHG, Duisburg, W. Germany). Cassava flour was prepared from cassava dried slices. The slices (½ x 2 x 6cm) were dried in an air draft assisted oven at 50°C for 72 hours, ground into fine flour using a coffee grinder and sieved using 710µm sieve. A buffer solution was prepared from 14.8g anhydrous disodium phosphate and 10.3g citric acid monohydrate made up to 1 liter with water. The amylograph was fitted with the 700cm. cartridge, 40g of cassava flour and flakes were weighed into 500ml beaker, then 46ml of the buffer solution and 360 ml of water were added

to the flour. The mixture was stirred with a plastic stirrer and the slurry poured into the amylograph bowl. The remaining content of the beaker was rinsed with further 100 ml of water into the amylograph bowl. The amylograph was set to run with temperature change of 1.5°C/min. Samples were heated from 25°C to 95°C (AACC, 1995).

Structure of cassava starch by microscopic method. The structure of starch in ungelatinised and gelatinised cassava flour and flakes suspensions (1%) with different emulsifiers were observed using the light microscope under phase contrast and polarised light (Olympus BH-2, Japan). The eye piece specifications were 3.3LNx 10. The type of film was 150 Konica colour print film.

Results and Discussion

Table 1 shows the sensory scores of reconstituted cassava flakes mash for taste, colour, stickiness, texture and general acceptability. It was observed that, samples with stearate monoglycerides tasted better than samples without emulsifiers and those with sodium caseinate and skim milk powder. Scores for colour showed that samples with stearate monoglyceride were even whiter than the mash from fresh cassava ($P \leq 0.05$) (Table 1 and Figure 1). Samples without emulsifiers were less white compared to the mash of fresh cassava. ($P \leq 0.01$). Samples with skim milk powder were slightly darker, while those with sodium caseinate were even more darker. The probable reason of this colour change is non-enzymic browning between sugars and amino acids in casein and skim milk powder during drum drying.

Scores for stickiness showed that the mean scores for samples with stearate monoglyceride were not significantly different from fresh cassava (≤ 0.01). The results showed that samples with skim milk powder and sodium caseinate were not significantly different from each other ($P \leq 0.01$), but were more sticky than the ones without emulsifiers.

Table 1: Mean scores for sensory evaluation of reconstituted cassava flakes with different emulsifiers.

Sample	Taste	Colour	Stickiness	Texture	General acceptability
Fresh cassava	4.70±1.31	4.00±1.55	0.50±0.33	4.0±1.20	4.60±1.56
No emulsifier	3.00±1.54	3.20±1.49	3.42±1.44	2.41±1.11	1.99±0.64
Sodium caseinate	2.70±1.09	2.24±1.38	4.85±1.26	1.70±1.16	2.32±1.81
Skim milk powder	2.51±1.46	2.86±1.47	4.70±1.31	1.83±1.19	2.48±1.87
Monoglyceride	4.10±1.37	4.40±1.28	1.22±0.88	3.90±1.24	4.31±1.75

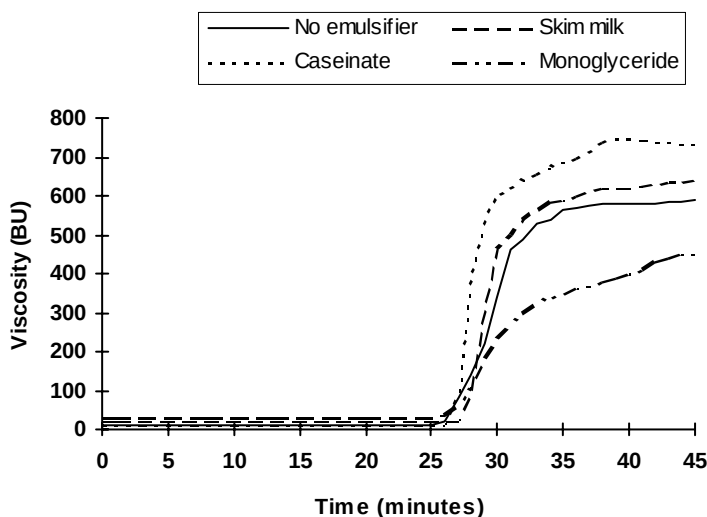


Figure 1: Effect of emulsifiers on pasting characteristics of cassava flour by the Brabender amylograph.

The texture of samples with stearate monoglycerides was not significantly different from fresh cassava sample ($P \leq 0.05$).

General acceptability of reconstituted cassava flakes mash samples with stearate monoglyceride was high approaching the scores for fresh cassava.

Pasting characteristics of cassava flour and flakes. Starch viscosity increases with gelatinisation, which is caused by swelling of starch granules. The high percentage of soluble amylose in starch may be responsible for the high viscosity values (Galvez and Resurrection, 1993).

Figure 2 show the results of the tests of the pasting characteristics of cassava flour determined using the Brabender amylograph. Samples with stearate monoglyceride had

lower viscosity ($P \leq 0.01$). This suggests that stearate monoglyceride has reduced the soluble amylose which is responsible for high viscosity by forming starch monoglyceride complex. Emulsifiers did not have an effect on the pasting temperature. It ranged between 63.5°C - 65°C.

These results agree with those obtained by Hoover and Hadziyev (1982), when they found that monoglyceride reduced swelling power and amylose solubility in potato. Eliason (1985) reported that formation of complexes prevent amylose leaching during gelatinisation, inhibit excessive shelling of starch granules when heated in water and reduced water binding capacity of starch. Narravo *et al.* (1995) also mentioned that monoglyceride reduces swelling and rupture of starch granules.

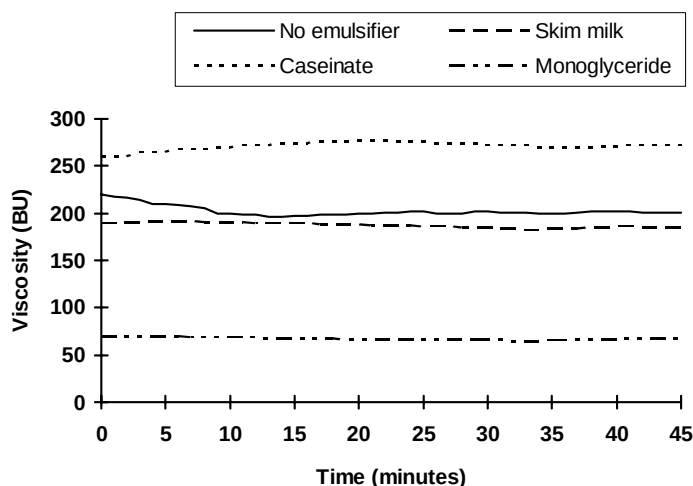


Figure 2: Effect of emulsifiers on pasting characteristics of cassava flakes by the Brabender amylograph.

The Brabender amylograph also showed that cassava flakes with stearate monoglyceride had lower viscosity ($P \leq 0.001$) compared to the flakes without an emulsifier and those with skim milk powder and sodium caseinate. There was no peak viscosity shown because the starch in the flakes was gelatinised already. Hoover and Hadziyev (1981a) reported that addition of monoglycerides in production of mashed potato is aimed at binding free amylose to control stickiness and glueyness of the product so in this case also, stearate monoglyceride bound the free amylose in cassava flakes.

Structure of gelatinised and ungelatinised starch granules. The structures of raw and gelatinised starch granules and cassava flakes with different emulsifiers were observed using a light microscope. They were observed under phase contrast and polarised light.

In samples without emulsifiers, starch granules were found to be clumped together while in samples with emulsifiers the starch granules were dispersed in water.

Raw cassava starch (10ml, 1%) with different emulsifier was heated (with continuous stirring) on a Bunsen burner for 1 minute. Starch granules disintegrated completely and the suspension was clear

(translucent). All starch granules in samples without an emulsifier and those with skim milk powder and sodium caseinate gelatinised and disintegrated completely while samples with stearate monoglyceride did not disintegrate completely.

The polarised light micrographs showed complete gelatinisation for samples without emulsifier and those with skim milk powder and sodium caseinate. Under phase contrast they showed some big particles, which may be due to aggregation of gelatinised starch granules. In samples with stearate monoglyceride, starch granules did not disintegrate completely.

Conclusion

Addition of stearate monoglyceride reduces stickiness, and makes the reconstituted cassava flakes mash acceptable. The colour of cassava flakes with stearate monoglyceride becomes whiter which even makes the product more attractive.

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The role of sweetpotato root and starch characteristics on thermally processed products

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Abstract. The significance of processing sweetpotato (SP) was investigated by assessing the characteristics of three new sweetpotato varieties (Tanzania, New Kawogo and Naspot 5) and a UK commercial (Jewel) variety. The characteristics of the roots (dry matter, sugar and amylase contents) and their respective starches (gelatinisation and pasting temperature parameters) were analysed. Tanzania and Naspot 5 SP root pulp had comparable dry matter (37.0-37.8%), reducing sugar (0.5%) content and alpha amylase activity (2.60-2.66 mg.g⁻¹.min⁻¹) as opposed to New Kawogo. Jewel variety had the lowest dry matter (19.0%), highest reducing sugar content (2.6%) and alpha amylase activity (7.78 mg.g⁻¹.min⁻¹). Variation in SP root characteristics might indicate post harvest changes or due to variety differences. The same ranking order of the starch varieties was followed for gelatinisation and pasting temperature parameters, with Naspot 5 having the highest, followed by Tanzania, New Kawogo and Jewel starches. Jewel and New Kawogo similarly showed comparable onset temperatures of gelatinisation and pasting that differed from Naspot 5 and Tanzania. Naspot 5 (15.6 J/g) and Tanzania (15.2 J/g) starches exhibited higher enthalpy of gelatinisation than Jewel (13.2 J/g) and New Kawogo (12.4 J/g), indicating that they may require high energy to disrupt their crystalline granule order. Jewel SP processed products are likely to have inferior sensory properties. Individual starch characteristics did vary but may be

used to select sweetpotato varieties for specific products.

Introduction

There is an increased interest in adding value to sweetpotato (SP) roots such that a broad range of SP products are provided to the consumer (Hagenimana and Owori, 1997; Hagenimana *et al.*, 1998). Presently SP is consumed as either boiled, roasted or baked. Dried SP chips and flour are popular products available in Eastern Uganda (CIP, 1998). The stability of these products during processing and storage are dependent on the composition of the roots and SP starch characteristics (Katayama *et al.*, 1999). Starch is the major constituent (60%) of the dry matter, and therefore the basis of SP products. However, other constituents such as sugars, lipids, and amylases influence the functional behaviour of SP starch during processing. Sweetpotato contains α -amylase that is concentrated at the periphery of the root tuber and β -amylase distributed throughout the root (Hagenimana *et al.*, 1992). These amylolytic enzymes have been utilised as a processing aid in the production of dehydrated SP flakes, mashes and purees, and may be used for production of ethanol (Vijaya and Basappa, 1997). On the other hand SP α -amylase has the ability to hydrolyse native (raw) SP starch, such SP functional properties are modified before it is further processed to stable products. Sugars are another SP

constituent that affects the functional behaviour of starch during processing by inhibiting starch gelatinisation (*starch conversion process*) and also cause browning of the processed products.

The above SP products are thermally processed via baking, roasting, steaming or drying (Susheelamma *et al.*, 1994), which involve gelatinisation of starch to various degrees depending on processing parameters. For this reason the composition of SP raw material will have an effect on the sensory attributes of its respective products, depending on the postharvest history of the roots. This paper provides an interpretation of the sensory quality attributes of the thermally processed products based on the SP root pulp and starch characteristics.

Materials and Methods

Varieties. Four SP varieties were procured for the study. Three of these were new viz. Tanzania, Naspot 5, and New Kawogo are Ugandan varieties, while the fourth, Jewel is a UK variety.

Starch extraction procedure. Starches from the SP roots were extracted according to the procedure of Collado and Corke (1997). Sweetpotatoes were washed under tap water, peeled and shredded using a food processor. The shredded SP pulp was added to 0.01% mercuric chloride, which was used as an enzyme inhibitor for amylases (Madamba *et al.*, 1975), at a ratio of 1:1 (w/w) and blended for 1 min at medium speed. The blended pulp was then filtered through a cheese cloth and the residue discarded. Starch in the filtrate was passed through a 250 mm sieve and left to settle at 18°C for 18 h. The supernatant was discarded and the sediment resuspended in distilled water and left to settle for another 2-3 h period. This step was repeated twice and starches left to dry at room temperature (18°C) for 18-19 h. Naspot 5 was resuspended in distilled water a fourth time to eliminate the intense orange colour. The dry starch mass pellet was broken to form a powder, gently

ground with a mortar and pestle, and a 250 mm sieve fraction retained.

Dry matter content. The dry matter content of SP root pulp was measured by drying samples (2 g) in a vacuum oven (Gallenkamp Oven 300 series, UK) at 80°C to a constant weight for about 20 h.

Amylase activity. Amylase (α - and β -) activity of the root pulp was assayed by incubating an aliquot (0.1 ml) of the enzyme extract at 40°C as described by Hagenimana *et al.* (1994 a). Enzyme extracts were prepared by blending 150 g of shredded SP pulp for 1 min in 450 ml of 20 mM sodium phosphate buffer (pH 6.0), containing 0.3% NaCl, 0.2% CaCl₂ and 5 mM β -mercaptoethanol (Hagenimana *et al.*, 1992). The blended material was filtered through four layers of cheesecloth. The filtrate was then centrifuged at 1350 g (3000 rpm) for 20 min (MSE Centrifuge, Multex, UK) and the supernatant kept in ice-cold water prior to the assay. The enzyme activity for α - and β -amylases was measured separately by determining the increase in reducing sugars of a 1% soluble starch solution gelatinised by boiling. For the α -amylase assay, soluble starch was dissolved in 16 mM sodium acetate buffer (pH 6.0) containing 5 mM CaCl₂ and 0.04% NaCl while for β -amylase assay in 16 mM sodium acetate buffer, pH 4.5 (Bernfeld, 1955; Hagenimana *et al.*, 1994 a). The optical density of the samples was measured at 540 nm using the LKB Biochrom spectrophotometer (LKB Biochrom, UK). A standard curve prepared using glucose (0-1.2 mg/ml) was used to convert the absorbance readings to total reducing sugar as mg glucose equivalents. Amylase activity level was reported as mg of glucose per g of dry SP pulp per min.

Sugar content. Sugars (*sucrose, maltose, glucose and fructose*) found in SP were measured enzymatically using Boehringer Mannheim GmbH, Biochemicals enzyme kits (R-Biopharm GmbH, Darmstadt, Germany) as

described by Namutebi (2002) and recorded as reducing and total sugar contents.

differences among the starch varieties at $P=0.05$.

Rapid viscosity analysis. Pasting profiles of starch suspensions were measured by a Rapid Viscosity Analyser (RVA) RVA-4 model (Newport Scientific, NSW, Australia). Starch samples (3 g), after correcting for the initial moisture of the starches, were dispersed in 25 g of distilled water in an aluminium RVA can to give 10.7% starch concentration. Starch suspensions were held at 50°C (1 min 15 s); heated from 50 to 95°C (7 min 30 s); held at 95°C (5 min); cooled from 95 to 50°C (7 min 30 s) and held at 50°C (1 min 45 s). The pasting and peak temperature parameters were recorded.

Differential scanning calorimetry (DSC). A Perkin Elmer DSC 7 (Perkin-Elmer INC., Beaconfield, UK) calibrated using indium (156.8°C) and cyclohexane (6.7°C) standards was used to study the gelatinisation behaviour of starches in excess water. An empty pan similar to the one used for the sample was used as the reference. Starch samples (2.5 mg) on a dry weight basis (dwb) were weighed into aluminium pans followed by 7.5 mg of distilled water and left to equilibrate overnight. The DSC thermograms were acquired over a temperature range of 10 to 100°C at 10°C min⁻¹ and gelatinisation parameters were computed using the Perkin Elmer Pyris software.

Statistical analysis. The data were subjected to a one-way analysis of variance to determine

Results and Discussion

Properties of sweetpotato root pulp. Table 1 shows the properties of the SP root pulp measured. Dry matter contents of the new SP roots ranged from 33.20 to 37.83 %, while Jewel SP (a commercial variety) had a dry matter content of 19.00 % (Table 1). All SP varieties had dry matter contents that were within the range (17.8-36.5 %) reported for other SP varieties (Obboh *et al.*, 1989; Hagenimana and Owori, 1997; Hagenimana *et al.*, 1998). The dry matter contents for Tanzania and Naspot 5 were however higher than the values reported by Ssebuliba *et al.* (2001). This could be attributed to different geographical localities and harvesting season for these new varieties. The low dry matter content for Jewel SP variety could be attributed to the post harvest history that was unknown or to varietal effects.

It is known that SP contains free sugars that arise when the SP plant is developing or during the post harvest handling of the root crop (Babu *et al.*, 1994; Hagenimana *et al.*, 1994 b; Morrison *et al.*, 1993). All SP varieties studied contained sugars, with the total sugar contents ranging from 9.5 to 14.3% (dry solids basis). The reducing sugar level was highest for the Jewel variety. Sucrose (non-reducing sugar) was the predominant sugar these varieties (Table 1). For most SP varieties, sucrose constitutes the bulk of sugars found in SP roots, followed by low amounts of

Table 1: Measurements[#] on sweet potato pulp.

Sweet potato variety	Dry matter (%)	Total sugars (%)	Reducing sugars (%)	α -amylase activity (mg.g ⁻¹ .min ⁻¹)	β -amylase activity(mg.g ⁻¹ .min ⁻¹)
Tanzania	37.83±0.84	9.53±0.24	0.52±0.20	2.63, 2.70(2.66)	2.99, 3.06(3.02)
New Kawogo	33.20±0.96	7.96±0.23	0.74±0.10	2.21, 3.28(2.74)	3.39, 3.43(3.41)
Naspot 5	37.03±0.23	10.36±0.10	0.47±0.10	2.57, 2.63(2.60)	1.97, 3.12(2.54)
Jewel	19.00±0.36	14.30±0.52	2.55±0.33	6.53, 9.03(7.78)	6.00, 6.56(6.28)

[#]Values are reported on a dry weight basis (dwb) of the sweet potato pulp.

fructose and glucose, with the exception of a few SP varieties that were found to contain maltose as the predominant sugar.

Reducing sugars are a key factor for non-enzymatic browning of products. Browning of products may impart an appealing or negative sensory quality attribute, depending on the products being processed. In addition, sugars affect the starch conversion process by reducing the gelatinisation temperature of starch subsequently influencing the processing parameters. It has been observed that heat processed products from SP result in highly browned products as compared to cereal flours (Namutebi, 2002) or even cassava flour. For thermally processed products, Jewel SP with highest reducing sugar content (Table 1) would undergo intensive browning compared to the other varieties which contained less than 1% reducing sugar level (dwb).

Each SP variety contained both α - and β -amylases (Table 1), which is typical of SP (Hagenimana *et al.*, 1992). Among the new SP varieties, New Kawogo had the highest α - and β -amylase activity, 2.74 and 3.41 mg.g⁻¹.min⁻¹, respectively compared to Tanzania and Naspot 5 SP. This would suggest that starch from New Kawogo might be prone to amylase hydrolysis if the roots are not appropriately handled after harvest. Jewel SP, the commercial variety, had substantially high mean levels of α - and β -amylase activities, 7.78 and 6.28 mg.g⁻¹.min⁻¹, respectively (Table

1). High sugar and amylase activity levels as found in Jewel SP variety have similarly been reported for the orange flesh US traditional cultivar known to have high amylase activity and sugar levels (Morrison *et al.*, 1993). However, it is possible that the high levels of amylase activity and sugar of the Jewel SP were due to its postharvest history, which was unknown. Hence the low dry matter, which could have been affected by the high α -amylase activity.

Gelatinisation parameters. Generally, thermal processing of starch involves moist heating of starch in a medium of water. Gelatinisation is the process of heating starch in excess water, where starch granules lose their native structure. Gelatinisation parameters of the starches were obtained by Differential Scanning Calorimetry (DSC). Table 2 shows the gelatinisation temperature parameters of the SP starches. Figure 1 shows the enthalpy of gelatinisation (DH) of starches, which is an indication of the amount of energy released when the amylopectin structure is disrupted during starch conversion. Naspot 5 starch had the highest DH, followed by Tanzania then Jewel. New Kawogo starch had the lowest DH (data not presented). This indicated that Naspot 5 and Tanzania starches require a higher energy input to disrupt their crystalline granule order compared to Jewel and New Kawogo starches. The DH for these SP varieties (12.5-15.6 J/g) were similar to DH

Table 2: Gelatinisation parameters and rapid viscosity Analyser (RVA) temperature parameters of sweetpotato starches.

Sweet potato variety	¹ DH (J/g)dwb	¹ To (°C)	¹ Tp (°C)	² RVA pastetemp (°C)	² RVA peaktemp (°C)
Tanzania	15.1, 15.3(15.2)*	71.77, 71.94(71.86)	75.33, 75.33(75.33)	75.02±0.28	85.60±0.30
New Kawogo	12.3, 12.6(12.5)	64.30, 64.70(64.50)	68.30, 69.30(68.80)	69.20±0.05	77.6±0.20
Naspot 5	15.8, 15.4(15.6)	73.15, 73.17(73.16)	78.33, 78.33(78.33)	76.73±0.03	85.80±0.10
Jewel	13.6, 13.1(13.4)	58.20, 58.21(58.20)	72.67, 73.00(72.83)	71.28±0.21	84.80±0.20

1. DSC gelatinisation parameters.

2. RVA temperature parameters.

*Values in parenthesis are means of the two respective values.

dwb: dry weight basis.

values reported for other SP starch varieties (Noda *et al.*, 1992; 1996; 1998).

Jewel and New Kawogo starches had low onset and peak gelatinisation temperatures (Table 2) showing they would gelatinise much earlier than Naspot 5 and Tanzania starches under similar processing conditions. Starches with high amylose content are assumed to show low onset (To) and peak (Tp) gelatinisation temperatures, and low DH due to a low proportion of amylopectin, the crystalline region. Although, Naspot 5 starch with the highest amylose content of $23.5 \pm 0.5\%$, had the highest DH and gelatinisation temperature parameters compared to New Kawogo with the lowest amylose content of $19.1 \pm 0.3\%$ (Namutebi, 2002). Previous work has shown that DSC gelatinisation parameters do not necessarily correlate with the proportion of crystalline starch granule regions, that is the amylose-amylopectin ratio but rather are influenced by the molecular architecture of crystallites related to the distribution of amylopectin unit chains, specifically the short unit-chains (Noda *et al.*, 1998). Noda and co-workers (1998) showed that starch with low DH, low onset and peak temperatures of gelatinisation had relatively abundant short unit-chains of amylopectin within the same botanical origin.

It is well established that sucrose increases the onset temperature of starch gelatinisation through an anti-plasticising effect on the amorphous fraction of the native starch granules when compared with water as the solvent. These varieties contained sucrose (non-reducing sugar) as the predominant sugar, therefore the processing conditions of SP starches will not only depend on the sugar content, but type of sugar. The monosaccharide sugars have been found to have a greater effect on the starch conversion process than disaccharide.

Rapid Viscosity Analyser parameters. The paste and peak temperature parameters of the starches give an indication of the processing conditions of specific starchy products. Naspot 5 starch had the highest RVA paste

and peak temperatures followed by Tanzania, then Jewel and New Kawogo (Table 2). Since pasting of starch in the RVA canister is a thermal event similar to gelatinisation of starch granules in excess water in the DSC pans, the DSC To and Tp temperature parameters of the four SP starch varieties followed a similar trend (Table 2). Varietal differences in RVA temperature parameters were observed for these SP varieties and have similarly been noted for other varieties (Katayama *et al.*, 1999). The RVA paste temperatures of the Tanzania and Naspot 5 starches were however higher than those reported by Katayama *et al.* (1999). New Kawogo and Jewel starches with low RVA paste and peak temperatures will cook faster than the Tanzania and Naspot starches under similar processing conditions.

Conclusions

Technologically starch is an important polysaccharide for a number of products where it serves as a binding or thickening agent to modify the textural property of products. Starch being the predominant component of sweetpotato influences the characteristics of SP products, which will however, depend on the structure of starch during its postharvest history.

This study endeavoured to interpret the relationship between SP root and starch characteristics to the processing and storage conditions and the likely sensory attributes of thermally processed products. Jewel SP variety with high amylase activity and sugar content, implies excessively browned products are obtained compared to the other varieties. Since Jewel SP variety is known to possess high amylase activity, it therefore would require specific handling conditions to minimise the effects of amylase on the starch. Likewise the high sugar content of Jewel indicates that it is not a suitable raw material for products, where minimal browning may be an important sensory attribute.

However, with regard to starch characteristics, Jewel starch variety did not apparently show marked differences in

gelatinisation and pasting parameters from New Kawogo. Implying the two would have similar processing functional properties. However, the composition of the respective roots that differed would influence their performance.

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Development and promotion of orange-fleshed sweetpotato varieties in Western Kenya

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Abstract. Vitamin A deficiency is a major nutritional problem in Kenya, leading to night blindness and high mortality of infants. Orange-fleshed sweetpotato (OFSP) varieties are being promoted as food based intervention to combat vitamin A malnutrition. Most of the OFSP varieties being promoted in Kenya are, however, not popular with farmers because of their poor adaptability and low root dry matter content. The only two OFSP varieties SPK004 and Zapallo with moderate consumer acceptance have not reached many farmers because of an inefficient planting material multiplication and distribution systems. New OFSP clones were evaluated at three sites in western Kenya between 2001 and 2002 in order to identify more clones with desirable characteristics. Clones 566632, 440248, 440208, 440031, Sponge, K118, and K135 were found to be promising in terms of root yield and taste qualities. Attempts were made to multiply and distribute planting material of the OFSP varieties using NGOs, community based organisations (CBOs), extension staff and farmer group partners working in area. A total of 49 million cuttings were distributed to 12,000 sweetpotato growers farmers within the two years.

Introduction

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is one of the world's highest yielding crops in terms of production per unit area, exceeding that of major cereals such as rice, and with higher food value (Woolfe, 1993). In Kenya,

sweetpotato is regarded as a "poor man's" crop because it is often grown and consumed by resource limited households and has the ability to give satisfactory yields under adverse climatic and soil conditions as well as under low or non-use of external inputs (Carey *et al.*, 1999; Ndolo *et al.*, 1998). It ranks third in importance after potato and cassava among root and tuber crops (Kung'u, 1999); however, it has become even more important in areas where cassava mosaic virus disease has devastated cassava (PRAPACE, 1998) and striga weed is a problem. As a food security crop, sweetpotato can be harvested piecemeal as needed, thus offering a flexible source of food and income to rural households that are mostly vulnerable to crop failure and fluctuating cash income. Additionally, it has a short maturity period of 3 to 5 months.

Sweetpotato is also important for human nutrition especially the orange-fleshed varieties which contain high levels of β -carotene used to combat vitamin A deficiency (Low *et al.*, 1996) in children under the age of five and breast-feeding mothers. Until very recently, relatively little emphasis was placed on OFSP varieties by researchers since farmers in Kenya were not used to the orange colour in sweetpotato. The scenario, however, changed after farmers realized that the OFSP varieties have higher food value in the form of β -carotene than the white or yellow types.

Earlier experiments in Kenya led to the identification of two OFSP varieties SPK004 and Zapallo which were fairly acceptable to farmers. However, Zapallo was later rejected

by many farmers because of its low root dry matter and its inability to withstand drought and high sweetpotato virus diseases. There was therefore a need to identify more OFSP varieties with acceptable agronomic and root qualities. Lack of well-organized seed distribution system for the vegetatively propagated crops in Kenya has also contributed to the slow rate of dissemination of the new varieties. New varieties are traditionally disseminated through farmer-to-farmer variety exchange and a limited sale of cuttings in the markets at the onset of the planting season. The objectives of this study were to involve farmers in the identification of new OFSP varieties and to use the existing NGOs, CBOs and farmer groups in the promotion of the varieties.

Materials and Methods

Identification of varieties. Two variety selection trials were conducted in Kenya between 2001 and 2002. The first trial consisted of OFSP clones introduced from other parts of the world through the International Potato Centre (CIP) while the second trial was made up of local OFSP cultivars collected from farmer's field in western Kenya.

Thirteen to 18 exotic OFSP clones were evaluated at KARI-Kakamega, Agolot village and Alupe sub-centre in western Kenya. KARI-Kakamega is situated in the Upper Midland one (UM1) agro-ecological zone at an altitude of 1585 m above the sea level and with annual rainfall of 1900 mm. The soils are well-drained, deep friable clay with humic topsoil (mollic nitosols) developed on tertiary or older basic igneous rocks. Agolot is located in Busia district at an altitude of 1220 m above sea level with a mean precipitation of 1790 mm. The soils are well-drained yellowish brown friable clay over petrolinthite (orthic ferralsols). Alupe is located at an altitude of 1250 m above the sea level and consists of moderately well drained, shallow, brown to dark brown soils over petro-plinthite (murram cuirass soils).

The clones were planted in a randomized complete block design with three replications. Each plot consisted of four ridges 4.5 m long and 100 cm apart. Each ridge was planted with 15 cuttings, 25-30 cm in length at a spacing of 30 cm between plants. The trial at Agolot was managed by the farmers in collaboration with Ministry of Agriculture extension staff and Rural Energy Food Supply Organization (REFSO), an NGO operating in the area. The trials at Alupe and KARI-Kakamega were managed by researchers but farmers from the surrounding were invited to evaluate the clones at harvest. Data were collected on virus infection using a scale of 1 to 5, where, 1=no virus attack and 5=severe virus infection. Reaction to drought was also assessed using a 1 to 5 scale, where 1=very susceptible to drought and 5=very resistant/tolerant to drought. At harvest, vines were cut at 10 cm above the ground and weighed. Storage roots were lifted and separated into marketable and non-marketable sizes. Marketable roots were those with cross sectional diameter at the largest portion of the root above 3 cm. The sum of marketable and non-marketable roots formed the total storage root yield. Dry matter content of roots was determined by oven drying a 200g-root sample for 48 hours. Five roots of each clone were cooked and evaluated by farmers using a score of 1 to 5, where 1=very poor taste and 5=excellent taste.

The second experiment consisting of seven local OFSP varieties was conducted for two seasons at Alupe sub-centre and KARI-Kakamega. Varieties were grown in 4.5-m plots of four rows, 100 cm apart. Cuttings were planted 30 cm from each other. The varieties were randomized within the blocks and replicated three times. Data were taken on virus infection, fresh weight of vines, storage root yield and dry matter contents of roots as described in the first trial.

Results and Discussion

Analysis of variance showed that there was significant site x variety interaction in all

parameters measured. Mean root yield was highest at KARI-Kakamega followed by Alupe. The high root yield at Kakamega was attributed to the high rainfall received during the trial period. Agolot had the poorest root yield as a result of the black cotton soil which compacted during the dry season and restricted the expansion of roots. Total root yields at Kakamega (Table 1) ranged between 15 and 49 tons/ha. Varieties 566632, 440248, 440208, 440031, 420014 and 440060 had higher root yield and dry matter content than the check variety Zapallo. All the best clones had acceptable root taste except for 440208. Although clones 566632, 440208 and 440060 had promising root yields, they were found to be susceptible to drought. Performance of the sweetpotato clones at Agolot is given in Table 2. The best clones at the site were 420094, 400014, 420054 and 400013. The results at Alupe (Table 3) showed that although clones 440208, 420009, 566632, 420094, 420001,

420286, 440248 and 420014 performed well, they were not significantly superior to Zapallo in terms of root yield. The dry matter contents of roots were higher than at Kakamega.

Mean performance of the local orange-fleshed varieties at Kakamega and Alupe was low compared to the exotic varieties (Tables 4 and 5) suggesting that the local accessions were either harvested before attaining their maximum maturity or they just have lower yield potential than the introductions. Varieties K44, K135 and K52 gave 17.1, 14.1 and 13.5 tons/ha of roots at Kakamega compared to 11.6 tons/ha obtained from SPK004 while none of the local varieties performed better than SPK004 at Alupe.

Promotion and dissemination of orange-fleshed varieties. While the selection of new orange-fleshed varieties was going on, researchers, extension staff, NGOs, CBOs and farmers' groups were involved in the

Table 1: Mean performance of exotic orange-fleshed varieties planted at KARI-Kakamega for two seasons.

Entry		Total root yield t/ha	Foliage wt T/ha	Virus score (1-5%)	Taste score (1-5)	Reaction to drought (1-5)	% DM
566632	-	49.2	25.4	2.3	3.3	2.4	23
440248	-	44.7	19	3	2.6	2.7	19
440208	Serenta	40.8	22	3.2	4	3.2	29
440031	-	36.9	14	3	3.6	3.4	27.3
420014	Jonathan	21	23.9	2.7	4.5	3.2	28.2
440060	TIB 4	21.9	10.2	2	2	2.6	27.2
440255	SP 094	21.4	13.4	4.3	3.5	3.3	19
440286	Bei jieng 553	22.5	15.4	3.6	3	3.7	25
420027*	Zapallo	20.2	23	4.3	2.9	2.5	14.5
LO-86-33	-	17.5	36	3	3	3.4	17.9
400014	Comote amarillo	16	33.6	3.2	4	3.6	22
420054	-	16.9	34.5	3.6	2	2.2	25.6
420009	Japanese	18.3	23.6	2.9	2.5	2.4	20.5
420094	Huanchano	15	14	3	2.9	2.6	29
187017	Salyboro	14.6	18.9	1.2	2	4	33.2
Mean		25.1	21.8	3	3.1	3	
LSD (0.05)							
CV %		9.4	10.8	0.8	0.6	0.7	
		33.6	41	14.3	20.4	19.7	

*Check

Table 2: Mean performance of orange-fleshed varieties planted at Agolot (Busia).

Entry		Total yield t/ha	No. of roots/plant	Foliage wt t/ha	Virus score (1-5)
440284	BIS 192	8.1	3	7.9	2.3
420001	Anaranjo itende	8.1	4	7.2	1.7
420094	Huanchano	12.1	4.7	15.7	1.7
440286	Bei jieng 553	8.1	1.3	6.7	1.3
400014	Comote amarillo	14.8	4	7	2.3
420054	-	9.6	3.2	9.2	1.3
440208	Serenta	7.5	4.9	3.8	3
420006	-	6	3.9	8.9	1.2
420019	Pedro	5.7	3.6	13.8	1.3
420005	Nemanete	6.4	3.8	7.3	2
400013	100092	9.3	4.7	8.1	2
420014	Jonathan	4	3.8	4.3	1.3
440151	LA10 44	6.4	3.9	9.4	1
Mean		8.2	3.8	8.4	1.8
LSD(0.05)		3.6	2.3	3.2	1.7
C V %		26.6	36.6	23	56.5

Table 3: Mean performance of exotic orange-fleshed varieties at Alupe sub-centre in western Kenya.

Entry	Total yield t/ha	Foliage wt T/ha	Virus score	Taste score (1-5)	Reaction to drought (1-5)	% DM (1-5)
440208Serenta	22.1	19.5	1.3	3.6	3	29
420009Japanese	21.9	29.6	2	3.2	3.3	26.2
566632 -	20.3	17.4	1.7	3.5	2.8	24.6
420094Huanchano	19.9	44.4	1.6	2.9	2.7	29.8
420001Anaranjo itende	19.4	20.2	2	3	2.9	27.6
440286 -	19.3	11.9	2	3.3	3.1	30
440248Jonathan	19	24.5	1.9	4	3.9	25.8
420014Zapallo	18.4	41.2	1.3	2.6	3.2	25.4
420027SP 094	17.9	15	4	2.4	1.6	17.6
440255 -	16.3	35	3.7	2.6	3.5	33.6
440031 -	15.2	29.3	3.9	3	3.5	26.8
440091Kafr El-layat No 1	13.3	26	4	3	2	25
440047Bugs buny	11.3	23.1	2	3.4	2.2	22.7
420054 -	7	14.1	2.3	3.2	2.6	28.9
187017Salyboro	8.7	56	1.2	3.5	2.7	30
440015 W-220	5.8	29.6	2.1	2.9	2.1	28
420005Nemanete	8.2	36.6	2.3	2.8	3.9	29.7
420019 Pedro	3.6	22.2	3	4	3.7	22
Mean	11.4	14.9	27.6	3.2	2.9	26.8
SED+	4.2	5.2	7.1	0.6	0.4	5.6
C V %	35.2	32.7	31.7	15.8	15.6	22

Table 4: Mean performance of local orange-fleshed varieties planted at Alupe sub-centre in western Kenya.

Entry	Total yield t/ha	Foliage wt t/ha	Virus score (1-5)	Taste score (1-5)	DM%
K118	15.7	36.9	1.7	4.5	26.8
K135	14.4	36.7	2	4	30
K207	1.5	52.9	1	3.6	29.3
K37	12.4	41.9	2.3	4	34.2
K44	4.4	41.2	1	4.2	29.8
K52	12.5	35.5	2.3	4.3	31.9
SPK004*	23	50	1	3.8	29.9
Sponge	13	47.4	2	4.5	32
Mean	12.1	42.8	1.7	4.1	
SED+	2.8	6.8	0.5	0.7	
CV %	28	19.5	12	15.6	

Table 5: Mean performance of local orange-fleshed varieties planted at KARI- Kakamega during 2001 and 2002 seasons.

Entry	Total yield t/ha	Foliage wt t/ha	Virus score (1-5)	Taste score (1-5)	DM%
K118	11.7	41	2.3	4.1	29
K135	14.1	36.1	3	3.9	31.3
K207	0.9	43.1	4	3.7	29.8
K37	1.3	39.4	4	4.2	30.2
K44	17.1	47.5	1.6	4	28.7
K46	8.8	40.3	2	4.2	30.3
K52	13.5	50	2.2	3.9	30.5
SPK004*	11.6	38.9	1.7	3.8	33.4
Sponge	6.1	48.1	3		
Mean	9.5	42.7	1.6	4	
SED+	3.5	9.1	0.6	0.5	
CV %	34.4	26	23.2	17.3	

promotion and dissemination of the existing orange-fleshed varieties to farmers. The NGO and CBO partners were selected from those already involved in agricultural activities. The main NGOs involved in seed multiplication and promotion of the orange-fleshed varieties are given in Table 6. The dissemination process of the OFSP varieties in western Kenya started with the on-farm selection of the varieties by the farmers. The selected varieties were bulked in primary multiplication sites at KARI-Kakamega, Alupe sub-centre, Yala swamp and Siaya FTC in western Kenya. Sweetpotato cuttings from these sites were

used by the partners to establish decentralized secondary seed multiplication units close to farmers. Planting materials from the decentralized seed bulking units were distributed to the group members or their neighbours either freely or at a cost. Some planting material from these plots were also purchased by other organizations and used to establish more secondary multiplication plots in other parts of Kenya. The amount of OFSP cuttings distributed to farmers by the different stakeholders is given in Tables 6 and 7. A total of 49 million cuttings covering 2700 hectares of land were distributed to farmers

Table 6: List of NGOs and CBOs partners involved in the promotion of orange-fleshed sweetpotato varieties in western Kenya.

Name of NGO	Operation areas (Districts)
Resource Project Kenya (RPK)	Vihiga
Christian Partners Development Agency (CPDA)	Vihiga
Africa Now	Vihiga, Kisumu
Ugunja Community Resource Centre (UCRC)	Siaya
Rural Energy Food Security Organization (REFSO)	Busia, Teso
Appropriate Rural Development Agricultural Programme (ARDAP)	Busia
Catholic Relief Services (CRS)	Migori, Rachuonyo
Rural Farm Alternatives Organization (RUFAO)	Bungoma
Community Research in Environment and Development Initiatives (CREADIS)	Bungoma
Akukuranut Development Trust (ADT)	Teso
International Christelijk Steunfond Africa (ICS)	Busia, Teso

Table 7: Number of the cuttings distributed and area planted in each district in western Kenya.

District	Amount of cuttings distributed x 10 ⁶	Area planted(ha)
Busia	13.0	680
Kakamega	6.8	340
Bungoma	3.1	150
Lugari	2.0	110
Teso	8.0	400
Vihiga	8.2	410
Butere/Mumias	2.7	200
Siaya	5.2	350
Kisumu	1.0	70
Total	49.1	2710

during the reporting period. The highest amount of planting material was given to Busia district as it had more NGOs involved in agricultural activities compared to other districts. A total of 102,000 households consisting of 511,000 people benefitted from the orange-fleshed varieties (Table 8).

In order to sustain seed multiplication efforts, partners were trained on the rapid multiplication techniques of planting materials (using 2-node cuttings; beds) and for maintaining them (plantings in well watered areas or in shaded areas near households). Efforts were also made to identify farmers with access to swamps or other permanently well-watered locations to serve as suppliers (in drier areas, presumably sellers) of planting

material. Quality of planting material was maintained through rejuvenation of multiplication plots with virus free planting material obtained from CIP, Muguga and rapidly multiplying these using tissue culture technique at KARI-Kakamega.

Promotion of OFSP varieties and their nutritional benefits was also done through agricultural shows, farmers' field days, from which participants departed with samples of cuttings to plant. Efforts were also made to use field schools or formal training institutions to popularize orange-fleshed varieties to the farmers and consumers. Attempts were also made to include ministry of health staff and village birth attendants in the promotion of the OFSP varieties.

Table 8: Number of households and beneficiaries of the orange-fleshed varieties in western Kenya.

District	Number of households	Number of beneficiaries
Busia	16400	82000
Kakamega	19000	95000
Kisumu	8740	43700
Siaya	6300	31500
Bungoma	7700	38500
Lugari	10600	53000
Teso	8800	44000
Vihiga	18000	90000
Butere/Mumias	6700	33500
Total	102,400	511,200

The approach also placed strong emphasis in training partners and farmers on sweetpotato utilization and nutrition including production of various sweetpotato-based products such as chapatis, chin chin, donuts, mandazis, juices, crackies, and weaning diets. Some members of the groups are already involved in commercial production of OFSP products. Training efforts in post-harvest utilization and nutrition have stimulated high interest among farmer groups on the orange-fleshed varieties. Participating NGO and CBO partners were used as trainers and models for the expansion of activities to other locations through training exercises and exchange visits.

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On-farm trials on long-term storage of sweetpotato at Gezaulole village, Kigamboni, Tanzania

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Abstract. The influence of store design on farm pre-treatment, storage site, type of soil and the nature of storage place (shade) on sweetpotato storage was assessed at Gezaulole village near Dar es Salaam, Tanzania. The design of the store had an influence on the storability of the fresh sweetpotatoes. Recovery of marketable tubers stored in pits constructed under shade was significantly higher ($P < 0.05$) than that from clamps. Preharvest pruning had no influence on the recovery of marketable sweetpotato tubers.

Introduction

In the tropics, sweetpotatoes are consumed or marketed soon after harvesting because their shelf life can be as short as one week (Rees *et al.*, 1998; Thomson *et al.*, 1997). In-ground storage (delayed harvest) is often not possible due to infestation by sweetpotato weevils (*Cylas* spp.). The seasonality of sweetpotato production leads to large fluctuations (3 fold) in market price and quality (Thomson *et al.*, 1997). Both producers and consumers could benefit if storage enabled sweetpotato to be marketed for a longer period of time (Hall *et al.*, 1998). In temperate areas, long-term storage of fresh roots is successfully practised. For example, in the United States sweetpotato can be stored for up to one year (Picha, 1986). In some cooler areas of the tropics, fresh storage is also practised. In the highlands in southwest of Tanzania sweetpotato are traditionally stored in cellars (T. Ngendello, personal

communication). In warmer regions, fresh storage is also feasible and has been demonstrated in Uganda, where in one trial sweetpotato were stored for up to 4 months (Devereau, 1995). Some of the trials, however, failed for reasons that were not clear.

Stores constructed in tropical climates vary with respect to type of store (pit, clamp and cellar), lining with dry plant material such as grass, cultivar, and quality of the roots.

Most stores are lined with dry plant material such as dried grass, bamboo, ash (Woolfe, 1992) or sand. The function of the lining and use of different materials is however not clear. It is thought it reduces sprouting and/or reduces the invasion by rats. It is speculated that the lining material insulates and reduces temperature changes, or that it modifies the storage atmosphere. The choice of cultivar can affect the storage success, because sweetpotato cultivars differ significantly in storability. When stored under marketing conditions (sacks) the weight loss per week for Polista and Sinia B and SPN/0 were between 8.4% and 10.3% and 7.8% and 10.7% per week, respectively (Van Oirschot, 2000; Rees *et al.*, 1998).

Damage to roots increases weight loss and reduces the storability of roots. Damaged areas form pathways for pathogens and for water loss. When roots are kept under curing conditions (27-29°C, and 95% RH), damaged areas heal.

Two types of stores have been reported in the literature: the pit and clamp type. Devereau *et al.* (1995) reported that roots

stored for longer in the pit rather than the clamp. In both cases however, storage performance was not consistent. Factors that affect performance of these stores are not known. This research aims to determine the time of storage and understand the relationship between store design, pre-treatment, site of the store, type of soils under which the stores are constructed and storage time.

Materials and Methods

Identification of the participants (farmers).

Fourteen farmers were identified to participate in the storage trial. This was done in collaboration with the Gezaulole village government.

Pruning of canopy of sweetpotato. Two groups of 7 farmers each were formed in order to facilitate the on-farm pre-treatment of sweetpotatoes. One group was asked to prune their sweetpotatoes in the fields 14 days before the storage exercise while the other group left theirs unpruned. Previous research (Bonte and Wright, 1993; Tomlins *et al.*, 1999) had indicated that pre-harvest curing of the tubers underground by removing the plant canopy 9 days before harvest might reduce the injury to the tubers during post-harvest handling and transport. This could lead to prolonged storage life of the tubers.

Store construction and design. A total of 56 stores were constructed for assessment of their ability to store sweetpotatoes for Dar es Salaam markets. Stores were constructed in the area under four different types of soils that are clay, loam, sand and calcareous soils. Each farmer constructed 4 stores (2 pits and 2 clamps). One pit and one clamp were constructed under shade while the rest were constructed in the open sun. In addition, a simple structure made up of wood and dry grasses was fabricated to protect each store from rainfall and heat from the sun. The pit comprised a circular hole of 70 cm diameter and 70 cm deep. The clamp comprised of a

raised bed of 100 mm of soil on which the mound of roots was piled. Table 1 shows the layout of the stores.

Storage of sweetpotato tubers. Each store was filled with 100 kg of freshly harvested sweetpotato. So each farmer stored 400 kg of sweetpotato. The tubers were covered with 10 cm of soil and jointly inspected every four weeks by farmers and researchers.

Market valuation. Sweetpotato market prices were assessed in two major sweetpotato markets (Tandika and Tandale) of Dar Es Salaam, Tanzania. Each individual farmer took the marketable roots to either of the markets for sale. The prices were then compared with the market price of fresh sweetpotato during the time of storage.

Inspection of stores. Stores were inspected every four weeks after storage to assess the tubers for rots, sprouting, shriveling and attack by weevils and vermins. Stores were also inspected for the general conditions of the storage structures in terms of protecting the tubers adequately.

Results and Discussion

Inspection of stores. By the fourth week, sprouting was observed in some stores with non- pre-treated sweetpotato. By the eighth week, tubers were sprouting in most treatments except in the clamp/un-pruned/open and clamp/pruned/open storage. Otherwise, they were still in good condition. By the third inspection (12 weeks), 13% of the tubers were rotten except those sampled from the clamp/pruned/open stores. Shrivelling was usually noticeable in clamp stores probably because of high temperature and humidity.

Recovery of sweetpotatoes. Much of the marketable roots were recovered from pits constructed under shade (51.7 and 55.0%). This was also reported by Tomlins *et al.* (1999) from studies done in the Lake zone. Table 2

Table 1: Layout of the stores.

No. of stores	Parameters combination
7	Clamp- not pruned (open)
7	Clamp –pruned (open)
7	Pit - not pruned (open)
7	Pit - pruned - (open)
7	Clamp- not pruned (under shade)
7	Clamp –pruned (under shade)
7	Pit - not pruned (under shade)
7	Pit - pruned (under shade)
56 stores	

shows the percent recovery of marketable sweetpotato tubers. Pruning had no effect on the recovery of marketable sweetpotatoes.

Suitability of sweetpotato tubers for different uses. Stores were opened after 16 weeks of storage. During this time, sweetpotatoes were sorted out into marketable roots, those fit for household use and rotten ones. Results are presented in Table 3. Percentage of tubers fit for household use was similar in all the stores. Percent rotten sweetpotatoes was highest in clamp/ pruned /open stores.

Table 2: Percent recovery of marketable sweetpotato tubers from various stores after 16 weeks.

Type of treatment	Mean
Recovery of sweetpotatoes	
Clamp/pruned/open	33.8 ^a
Clamp/pruned/shade	40.8 ^a
Clamp/not pruned/open	29.4 ^a
Clamp/not pruned/shade	44.0 ^a
Pit/pruned/open	37.3 ^a
Pit/pruned/shade	51.7 ^b
Pit/not pruned/open	36.4 ^a
Pit/not pruned/shade	55.3 ^b

Effect of soil type on sprouting of sweetpotato.

The lowest sprouting (8%) was recorded in the stores constructed in calcareous soils, while the highest (45%) was found in the stores constructed in the clay soils. This may not be serious because previous studies showed that sprouting was not a problem in marketing sweetpotato tubers (Tomlins *et al.*, 1999).

Marketability of the stored sweetpotatoes.

Market prices of the sweetpotato increased from Tsh 11,500 to 14,500 in both markets. Storage method never affected prices.

Table 3: Suitability of sweetpotato tubers for use after 16 weeks of storage.

No. of stores	Store types	Fit for household use	Rotten
7	Clamp/pruned /open	16.2	50.0
7	Clamp/pruned/shaded	25.0	34.2
7	Clamp/not pruned/open	31.0	39.0
7	Clamp/not pruned/open	31.0	39.6
7	Clamp/not pruned/ shaded	28.0	28.0
7	Pit/pruned/open	27.0	35.7
7	Pit/pruned/shaded	26.0	22.3
7	Pit/not pruned/ open	28.0	35.6
7	Pit/not pruned/ shade	21.0	23.7

Conclusion and Recommendation

Pit storage which is constructed in shade has the ability to store fresh sweetpotatoes for about 16 weeks. Clamp storage, although seemingly easier, results into more rots. Pruning the canopy of sweetpotatoes 14 days before harvesting the tubers for storage had no effect on the recovery of marketable tubers.

Therefore, farmers are encouraged to store their sweetpotatoes in pits constructed in shade. The cost of pruning sweetpotato before harvest and storage is not justified.

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Successful restoration of cassava production in Western Kenya

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Abstract. Cassava is an important staple food for consumption and income generation for farming communities in Western Kenya. The region grows and consumes 60% of the national cassava production. Between the years 1994 – 1995 a virulent form of cassava mosaic disease devastated all traditional cassava varieties. Production and productivity of the crop completely declined. Yield loss incurred in 1998 due to CMD was estimated at 15,000 tons valued at US\$ 10 million. In response to the magnitude of the problem, Kenya Agricultural Research Institute (KARI) collaborated with International Institute of Tropical Agriculture to mitigate cassava mosaic disease and other important agronomic characteristics. Fifteen desirable clones were bulked for seed through a three-tier multiplication scheme (primary, secondary and tertiary) to ensure equitable, fast and sustainable distribution of healthy planting materials. The clones which are multiplied and distributed were: SS4, Migyera, MM96/5280, MM96/1871, MM96/4466, MH95/0183, MM96/7688, TME – 14, MM96/4884, MM96/3868, MM96/9308, MM96/4684, Unknown 2, MM96/7151, MM96/9362. Over 34 million stems from primary sites have been distributed to farming communities. The coverage under improved cassava is approximately 13,000 ha., which is 38% restoration of the crop. Over 300,000 households are growing improved cassava in Western Kenya. Fresh cassava tubers and processed cassava products are now available on local and urban markets in the region.

Hunger, famine and poverty have been addressed by successful restoration of cassava production in Western Kenya.

Introduction

Cassava (*Manihot esculenta* Crantz) is a major source of dietary energy for a large population in tropical Africa. It enhances household food security and is a source of income. It provides livelihood to 100 million people globally (Legg, 1999). In Kenya, cassava is grown in Western, Eastern/Central and Coastal regions. The crop provides 9% of the total calories in the diet of Kenyans (Republic of Kenya, 1990). Western region of Kenya grows and consumes 60% of national cassava production. In many districts of Western region of Kenya, cassava is the staple food crop. Cassava is mainly grown in intercropped with beans, maize and bananas.

Cultivation and production of cassava crop in the region is constrained by biotic and abiotic factors. Non use of healthy planting materials, and improved agronomic practices and limited range of improved processing technologies affect production of the crop. The most devastating abiotic factor in the recent years is cassava mosaic disease. In Nyanza, yields declined from 6 - 3 tons of fresh tubers. In Teso district, the area under cassava production reduced to 1000 ha. from 3000 ha. annually (MOA and RD) Annual Report 1997/1998). Yield loss experienced in 1998 due to CMD was estimated at 150,000

tons valued at US\$ 10 million.(IITA Annual Report 1998).

Considering the implications of the disease it became extremely necessary to halt spread of the pandemic. Intervention measures that were considered essential to mitigate the scourge were introduction and evaluation of germplasm for resistance to ACMD and other agronomic characteristics. Cassava clones which were desirable, adaptable and acceptable were rapidly multiplied and distributed to the farming communities in Western Kenya (Project Report 2001/2). This paper describes steps which were adopted to restore production of cassava in Western Kenya.

Materials and Methods

The study was implemented by multiple stakeholders. These included KARI, IITA, extension personnel of the Ministry of Agriculture, Non-governmental organizations, Community based organizations, farmer groups, civic leaders and administrators. The approach used was participatory involved a series of targets that are logically circular and potentially recycling of basic activities – diagnosing the problem, identifying solutions, testing and adopting the technology while incorporating farmers' evaluation of the technology. Awareness forums and intervention measures spelt out partner roles. The following activities were carried out:

(a) Monitoring and diagnostic surveys. Surveys were conducted in the Lake basin region to track the progress of the pandemic from 1995-2002.

(b) Germplasm introduction and evaluation. A large number of cassava germplasm were introduced into Kenya. These materials were evaluated for resistance to CMD. Promising materials were advanced through preliminary and advanced yield trials and adaptability trials on-farm in different agro-ecological zones. In addition to diseases and pests these

clones were also evaluated for yield potential, cyanogenic and dry matter content.

(c) Multiplication. The project ensured that farmers in the region obtained sufficient healthy planting materials of improved, high yielding varieties which were also resistant to cassava mosaic disease (CMD). A three-tier multiplication system was adopted. This included bulking the materials at primary sites on institutional farms, then at secondary sites organized and managed by district steering committees and tertiary sites which were organized and managed by NGOs and CBOs in the region. Individual farmers were also involved in multiplication at tertiary level. The system aimed at decentralising the seed delivery system to ensure that all farmer groups got seed.

(d) Trainings. Technical information on cassava production was disseminated through awareness creation sessions, trainings, demonstrations, field days, workshops and stakeholder meetings.

(e) Monitoring and evaluation. Various fora were put in place to ensure broad participation for efficient and effective implementation of the project. This included establishment of regional steering committees, National steering committee and district steering committees. The committees ensured that work-plans were followed.

Results and Discussions

Monitoring and Diagnostic Surveys. Diagnostic surveys revealed that CMD disease was spreading from Uganda into Kenya at a rate of 40 km per year (Gibson *et al.*, 1996). The disease now covers the whole region up to the boarder of Kenya and Tanzania. The approach adopted was to introduce improved varieties in areas where the disease had already devastated the crop and in areas threatened by the disease. Infection rates on cassava in Busia, Teso, Bungoma and Siaya were between 75% and

Table 1: Summary of diagnostic survey of CMD status (years 2001 and 2002).

Year	Province	Cutting infection incidence	Whitefly infection incidence	Total	Severity ¹
2001	Western	55.1%	2.1%	57.2%	3.1
	Nyanza	41.6%	1.3%	48.9%	2.7
	Mean	48.4%	4.7%	53.1%	2.9
2002	Western	4.5%	3.8%	49%	2.8
	Nyanza	51.4%	3.0%	54.4%	2.7
	Mean	48.3%	3.4%	51.7%	2.75

100%. Spread was largely by cuttings though large swarms of whiteflies were evident. Disease severity was almost maximum in most areas. The infection rate in Butere, Mumias, Kakamega and Vihiga during the same period of was between 65% and 70%. Further to the south in Kisumu and Nyando districts infection ranged between 30% and 50%.

Data from the most recent surveys (year 2001 and 2002) revealed that CMD disease pressure has declined. Total infection was compared to low in Western province than Southern Nyanza (Table 1).

Germplasm and exchange and evaluation.

Since 1997 a total of 1408 cassava germplasm have been introduced into Kenya. In 1998, two clones, SS4 and Migyera were released for multiplication and distribution to the farming communities. In the year 2001, thirteen more clones were released for multiplication and distribution. The clones were; MM96/5280, MM96/1871, MM96/4466, MH95/0183, MM96/7688, TME-14, MM96/9362, MM96/7151, MM96/4884, MM96/3868, MM96/9308, MM96/4684 and unknown 2. All these are resistant to cassava mosaic disease (CMD), over 20 tons/ha under farmers management. They are also early maturing (taking between 12-14 months) and are preferred for cooking, culinary purposes and flour milling.

3. Rapid multiplication and distribution.

Multiplication of selected materials was conducted. Currently the area under improved cassava clones is 13,000 ha. which is 38% restoration of cassava in Western Kenya. Over 300,000 households grow these improved cassava varieties.

4. Capacity building. Over 3,000 farmers and agricultural workers have been trained in all aspects of cassava production and control measures of CMD, rapid multiplication of CMD free planting materials, processing and utilization. The efforts were aimed at making cassava production sustainable in the region.

Summary

Monitoring and diagnostic surveys, germplasm introduction, three tier multiplication and distribution arrangements and capacity building of the agricultural workers have proved to be a successful technology transfer method against the CMD pandemic in Western Kenya. It has enabled rapid multiplication and distribution of large quantities of improved CMD resistant varieties to many farmers in a relatively short period. Cassava growing has been restored in Western Kenya.

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Minimal processing of yam to increase consumers' acceptance

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Abstract. Studies were carried out on the minimal processing of yam, a value staple crop among the Ghanaian populace. Yam, reduced to different sizes was minimally processed using two methods (steaming and parboiling). These samples were stored at -20°C over a period of 12 weeks. Sensory evaluation involving 2 sets of panel to assess Product-based and Consumer-based influences was conducted on the stored samples every fortnight to evaluate the colour, texture, taste and size of the yam sample after frying and boiling. Product-based testing for parboiled *pona* shows that taste and colour for the large size yam was the most preferred and it was stable throughout the analysis. The large type also shows that preference increased with storage especially for size and texture. For the steamed pretreated, preference decreased with storage for small type samples while for chips all the four sensory parameters were acceptable to the consumers. There were varying preferences in some of the sensory parameters for small and medium types. The result of the parboil samples for the consumer-based analysis indicated that with exception of taste all the other sensory parameters were acceptable for both small and large sizes while for medium size and chips preference was for size, and texture. For the steamed samples panelists showed preference for all the sensory parameters for chips while for small size preference decreased with storage. There was a general acceptance for steamed treated chips in both product and consumer based

testing. With exception of taste in the consumer-based testing all the other sensory parameters in both testing were well accepted.

Introduction

Yam (*Dioscorea* spp.), one of the most important staple crops in Ghana, is used in various forms in food preparations such as *ampesi* (boiled yam), *fufu* (pounded boiled yam), *oto* (mashed boiled yam), fried and *mpotompoto* (yam porridge). However, it is predominantly eaten as *ampesi* and fried chips.

Pona (*Dioscorea rotundata*) is one of the yam species commonly cultivated and consumed by Ghanaians as a staple food. However, lack of effective post-harvest storage methods affect its shelf-life, thus leading to huge economic losses whenever there is a bumper harvest. One of the innovations whose impact on post-harvest technology is increasing, is “minimal processing” of fruits and vegetables. “Minimal processing” generates products that are cut and lightly processed in order to make them easily used by consumers. Considerable data concerning the use of “minimal processing” technologies can be found in literature (Ohlsson and Bengtsson 2002). However, there is a paucity of data in the use of these techniques for yam. Also, with the changing lifestyle in our society, there is an increase in the demand for semi-processed and processed foods, thus the need for an increase in the number of minimally processed

food types to meet these demands. This study sought to determine the product stability with respect to its sensory characteristics during storage and its consumer acceptability by adapting the technology of minimal processing.

Materials and Methods

Source of yam tubers. The *pona* yam tubers were obtained from a local yam seller at Patasi a suburb of Kumasi, Ghana.

Processing and storage of samples. The yam tubers were peeled, washed and processed in two groups: the first group was cut into chips using a potato chipper and in the second batch; the peeled yam tubers were cut into pieces of three different sizes (Small – 1.5 cm; Medium – 2.0 cm; Large – 3.0 cm and Chips). These were washed and further subdivided into two groups. Samples in one subgroup were parboiled while the other subgroup samples were steamed according to the time periods shown in Table 1. After the heat treatment, the samples were cooled in cold water, packaged in low-density polyethylene bags and stored in a freezer over a 12-week period at –20°C.

Preparation for sensory analysis. Both fresh and freeze-stored preheated yam samples were cooked. The yam chips were fried in ‘Leisure’ vegetable oil, using the Kenwood Di-460 deep fryer. The oil was heated to a temperature of 190°C prior to frying and the temperature maintained during the period of frying. The

chips were fried until golden brown. The other types were cooked in boiling water. The stored samples were cooked in their frozen state to reduce the effect of freeze injury. The periods for boiling and frying are also indicated in Table 1.

Sensory evaluation. The sensory analysis was conducted using a hedonic scale of 1–7 with responses ranging from dislike very much through neither like nor dislike to like very much respectively. Sensory analysis was done to determine the effect of the type of pretreatment as well as the effect of the storage method (freezing) on four parameters: taste, colour, texture and size of yam samples. Evaluations were carried out fortnightly. Fresh yam samples prior to storage served as controls.

Two types of data were collected: data on product-based analysis (in which the same sensory panelists were used throughout the period of the analysis) and data on consumer-based analysis (where panelists were varied over the period of the analysis). An untrained panel of 40 individuals was used for the consumer-based testing and 20 individuals for the product-based testing. The mean response was determined for each sensory parameter analyzed. The sample was considered acceptable by the panel if the mean value obtained falls within the range of 4 - 7.

Data analysis. The complete randomized design (CRD) was employed in this study and the analysis of variance (ANOVA) of the data was computed at $P < 0.05$.

Table 1: Time for parboiling, steaming and cooking.

Type	Pre-treatment		Cooking (min)
	Parboiling (min)	Steaming (min)	
Small type	3	6	8
Medium type	4	7	10
Large type	5	9	15
Chips	2	4	6

Results and Discussion

Product-based analysis - Parboiled *Pona*.

Panel response to taste over the 12-week analysis was generally in the acceptable range for all samples except for the large type, which at some point fell below the acceptable range. The small and large types were acceptable while the medium type and chips were at certain periods below the acceptable range in terms of colour. The poor response to colour for the chips and the medium type may be attributed to discoloration due to enzymatic browning (Akorada, 1995; Fennema, 1996). The results also showed no significant variations in colour. Texture of the large type and chips were the most accepted over the period of analysis. The large type gave the best texture response with a mean value of 5.88. The chips showed a high response at 5.36 and a low of 4.00. Both small and medium types however had responses at certain periods below the acceptable range during the course of the evaluation. ANOVA results indicated no significant differences ($P < 0.05$).

For size, all the types were within the acceptable range though the medium type showed the highest mean-value response of 5.82 (Table 2).

Product-based analysis - Steamed *Pona*. The mean-values of response to taste showed that the chips were highly accepted, with the highest mean-value response of 5.67 and the least at 5.06 (Table 3). The responses for the small (the least accepted sample), medium and large types showed a fluctuating trend in the response range of 3.08 to 5.18. ANOVA results for taste of the samples indicated significant differences in taste ($P < 0.05$). The colour of the chips was acceptable and that for the small type the least accepted. Chips showed a generally high and stable response with a high mean-value of 5.83 and a low mean-value of 4.60. The remaining samples (small, medium and large types) at some point during the evaluation were out of the acceptable range. The poor response to colour shown by the small type may be attributed to browning reactions (Fennema, 1996). For the response

Table 2: Mean range of sensory evaluation for product-based study (Parboiled).

Type	Parboiled <i>Pona</i>			
	Taste	Colour	Texture	Size
Small	3.47-4.55	4.00-5.59	3.50-5.00	4.85-5.18
Medium	3.22-4.36	3.43-5.05	3.89-4.86	4.61-5.82
Large	4.35-5.41	4.33-6.28	4.57-5.88	4.25-5.53
Chips	3.89-5.21	3.00-4.83	4.00-5.36	4.38-5.55

Table 3: Mean range of sensory evaluation for product-based study (Steamed).

Type	Steamed <i>Pona</i>			
	Taste	Colour	Texture	Size
Small	3.08-4.50	2.88-5.31	3.56-5.50	3.90-5.30
Medium	3.77-5.18	3.15-5.56	3.38-4.84	4.76-6.30
Large	3.29-5.06	3.55-5.08	3.94-5.20	3.50-5.66
Chips	5.06-5.67	4.60-5.83	5.15-5.83	5.00-6.00

on texture of the samples, chips gave the best results over the period of the analysis, showing a high mean-value of 5.83 and a least value of 5.15. Large type showed a fluctuating trend for texture response, which was between 3.94 and 5.20 over the period of the analysis. All the other types also showed fluctuation in response. Results on texture showed significant differences ($P < 0.05$), which may be due to freeze storage effect. In the case of size, the chips were the most accepted and the large type, least accepted. The highest mean-value for the chips was 6.00 and its lowest mean-value was 5.00. The large type indicated a high mean-value for taste of 5.06 and the least value of 3.29. Both chips and medium types gave a relatively stable acceptable trend for response to size during the analysis. With regards to the small type, there was some fluctuation in response. ANOVA at $P < 0.05$ indicated significant differences in the size of the samples. The observation made during the evaluation showed that there was a fluctuating trend in terms of product stability. This could be due

to differences in perception and freeze-storage effects resulting in sogginess and, or, discolouration.

Consumer-based analysis - Parboiled Pona.

The response to taste for all types was at certain periods below the acceptable range (Table 4). However, for the large type, the most accepted showed a high mean-value at 5.15 and a least value of 3.97. ANOVA results showed no significant differences ($P < 0.05$) in the taste responses between the samples. For colour, the large type was the most preferred. The highest mean-value for the large type was 5.89 and the least 4.57. The small type was also stable throughout the period but there was fluctuation in preference for the chips and medium type. The poor response to colour could be due to discoloration brought about by freeze-storage effect. The response to the texture of the chips was the most acceptable with its highest value of 5.52 and the least at 4.19. The responses to the texture of the small type were relatively stable except for the 12th week. Medium and large types were also in

Table 4: Mean Range of sensory evaluation for consumer-based study (Parboiled).

Type	Parboiled Pona			
	Taste	Colour	Texture	Size
Small	3.77-4.71	4.26-5.28	3.93-4.94	4.74-5.20
Medium	3.18-4.86	3.55-5.02	4.21-5.18	4.62-5.72
Large	3.97-5.15	4.57-5.89	4.69-5.43	4.20-5.08
Chips	3.85-5.34	3.17-5.59	4.19-5.52	4.31-5.35

Table 5: Mean range of sensory evaluation for consumer-based study (Steamed).

Type	Steamed Pona			
	Taste	Colour	Texture	Size
Small	3.32-4.70	3.57-5.27	3.57-5.27	4.34-5.25
Medium	3.23-5.00	3.25-5.29	3.18-5.14	4.54-5.47
Large	3.65-4.97	3.94-5.42	3.91-5.45	3.71-4.62
Chips	5.06-5.78	4.28-5.90	4.88-6.00	4.88-5.55

the acceptable range throughout the evaluation period. ANOVA results showed no significant differences ($P < 0.05$) in responses to texture of the samples. For the medium type, the most preferred had a high mean-value of 5.72 and least of 4.62. All the other types were also within the acceptable range. ANOVA calculations indicated significant differences ($P < 0.05$) in perception of size.

Consumer-based analysis - Steamed *Pona*.

Chips had the highest mean-value of 5.78 and the least value of 5.06 (Table 5). A fluctuating trend for response to taste for all of the other types was observed over the period of the analysis. ANOVA results for taste indicated significant differences ($P < 0.05$). Colour of the chips was highly accepted with the small type being the least accepted. The highest mean-value for colour for the chips was 5.90 and the least value was 4.28. For the medium types, there was a declining trend during the period of analysis showing a high mean-value at 5.29 and a low value of 3.25. The large type also showed a fluctuating trend. The poor response to colour observed might be attributed to discoloration or browning of the samples during storage. There was a significant difference ($P < 0.05$) in colour. Response to texture also showed chips having the most preferred response with least mean value of 4.88 and highest mean value of 6.00. The large type showed a high mean-value of 5.45 and a low value of 3.91. The response for the small and medium types was also fluctuating as storage time increased. The size of the chips was the most accepted with its highest value at 5.53 and a least value of 4.88. For the medium type, the highest mean-value was at 5.47 and the lowest at 4.54. The small type showed a high mean-value of 5.37 and low value of 4.34. The least accepted sample, the large type showed a high value of 4.62 and low value of 3.71. There was a significant difference in responses.

Conclusion

The results from this studies show that significant changes in sensory parameters were influenced by perceptual differences of the panelists as well as effect of freeze-storage. However, chips were judged most acceptable throughout the 12 weeks of sensory evaluation of the steamed *Pona*. The large type, in terms of parboiled treatment, was more accepted. The product- and consumer-based studies showed that steamed chips and parboiled large types were the most preferred. This study has shown that minimal processing of yam using steaming for chips and parboiling for large types has a great potential especially since yam is predominantly eaten as *Ampesi* and fried chips. It is hoped that this study will provide a fundamental basis for future studies using minimal processing technology on yam.

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Determinants of farmers' adoption of improved cassava and sweetpotato varieties in Sierra Leone

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Abstract. The capacity of most African countries to produce enough food for their people is declining in the face of a rapidly increasing population and civil conflicts leading to dependence on food imports and food aid. Adoption and sustenance of farm technologies that can help enhance food production remain a major challenge for research and development agencies in many African countries. Over the years, the Institute of Agricultural Research (IAR) has made substantial efforts in improving the productivity of small-scale farmers in Sierra Leone through the development of improved technologies. This paper is based on a survey of 280 farmers in six operational zones of IAR in Sierra Leone. The results show that improved cassava and sweetpotato varieties developed by the institute have been adopted not only by farmers who have collaborated with IAR in developing and testing these technologies, but by other farmers too. The results however indicate that among other constraints, the adoption of the improved varieties is inhibited considerably by limited finance and lack of high yielding and disease-free planting materials acceptable by both the producers and consumers. The findings further suggest that farmers' religion, marital status, sex, income sources outside agriculture and collaboration in on-farm research are important in influencing adoption and should therefore be taken into consideration by research and development agencies in the promotion of root and tubers crops in Sierra Leone.

Introduction

The capacity of most African countries to produce enough food for their people is declining in the face of a rapidly increasing population and civil conflicts leading to dependence on food imports and food aid. Adoption and sustenance of farm technologies that can help enhance food production remains a major challenge for research and development agencies in many African countries (Chitere and Kiros, 1996). The goal of agricultural research centres is to generate technologies for improving productivity, farmers' welfare, and household nutritional status (Sangiga *et al.*, 1999).

In Sierra, like in most African countries, agriculture is of vital importance to the livelihood of millions of people as a source of food, employment and foreign exchange. The ten years war in Sierra Leone has aggravated the food situation problem as a large number of farm families were forced to flee bringing their agricultural activities to a halt. Even before the war, agricultural production was declining. Although the war is over, food production has not regained pre war levels. The country depends a lot on imported food (especially for the staple food rice) and on food aid (FAO, 200).

Over the years, the Institute of Agricultural Research (IAR) has made substantial efforts in improving the productivity of small-scale farmers who make up the bulk of food producers in Sierra Leone, through the development of improved

technologies which involve the introduction of high yielding plant materials that are resistant to pests and diseases, and the use of improved agronomic and management practices. IAR has the mandate to conduct research on the improvement of cassava, sweetpotato, yams, maize, groundnut, cowpea, and soybean.

However, the ultimate usefulness of these technologies is determined by their adoption by their adoption levels by the small scale farmers (Inaizumi *et al.*, 1999). The adoption of a new agricultural technology is important for evaluating the impact of agricultural research investments, guiding technology development to satisfy the needs of clients, and also helps bring out potential impact at the farm household level (Sanginga, 1988, Inaizumi *et al.*, 1999). It is therefore important to assess the technological packages to find out if they meet the farmers' objectives. This will contribute immensely to technology transfer and facilitate the task of addressing the objectives of food security, malnutrition and poverty alleviation.

The objective of this paper is to assess the determinants of farmers' adoption of improved varieties of cassava and sweetpotato. In particular, the paper examines the rates of adoption of these varieties, the constraints that limit the adoption and the factors determining adoption. The basic hypothesis formulated for this study is that the socio-economic characteristics of farmers are important in explaining their adoption behaviour.

Materials and methods

The survey was conducted in six operational zones of IAR. These include: Njala, and Bo in the Southern Province, Kenema in the Eastern Province and Rokupr, Makeni and Kabala in the Northern Province. The zones are representative of the ecological and traditional diversity in Sierra Leone. Twenty five IAR contact farmers and 25 non IAR contact farmers were then randomly selected per zone and involved in the study. Questionnaires

were then administered to the farmers to collect information on their socio economic and demographic characteristic, rate of adoption of improved IAR cassava and sweetpotato varieties, effect of socio economic and demographic characteristic of farmers on adoption, production constraints, etc. Data were analysed using descriptive statistics such as averages and percentages as well as a logistic regression analysis to examine the effect of the socio-economic characteristics of farmers on the rate of adoption of IAR technologies.

Results and discussions

Socio economic characteristics of sampled farmers. Twenty farmers never returned the questionnaires. So the analysis is based on 280 farmers. Table 1 presents a summary of selected socio-economic characteristics of farmers interviewed. This table reveals that contact farmers had a mean household size of 9.5persons compared to 7.9persons for non-contact farmers. The higher family size for contact farmers is an indication of the potential labour force as well as the number of people to be fed. The mean age in the case of contact farmers was 43.2 years and 43.0 years in the case of non contact farmers, indicating that the respondents are in the active producer age group and could contribute greatly to productive work on the farm.

There were more women among non-contact farmers (29.3%) as compared to contact farmers (15.78%), which might be due to the fact that the number of female IAR contact farmers is low when compared to their male counterparts, a situation which IAR is trying to correct by deliberately targeting women as contact farmers. On the whole, the number of women farmers was very low (22.5%) compared to male farmers (77.5%). Majority of the farmers were married (95.7% of contact farmers and 90% of non contact farmers). This might not be surprising since marital status tends to influence the potential

Table1: Selected socio economic characteristics of farmers.

Characteristics	Total		Total number of farmers	
	Contact farmers (N=140)	Non contact farmers (N=140)		
Household size				
Mean	9.5	7.9	9.3	
Standard deviation	4.9	4.4	4.6	
Min	1	3	1	
Max	39	29	39	
Age				
Mean	43.2	43.0	43.1	
Standard deviation	11.3	5.7	11.1	
Min	17	19	17	
Max	80	72	80	
Gender	N	%	N	%
Male	118	84.3	99	70.7
Female	22	15.7	41	29.3
Marital status	N	%	N	%
Married	134	95.7	126	90
Not married	6	4.3	14	10
Literacy level	N	%	N	%
None	42	30	42	30
literate	98	70	98	70
Occupation	N	%	N	%
Full time farmer	104	74.3	81	57.9
Part time farmer	36	25.7	59	42.1

availability of family labour, which is very important for the farm families.

Both contact and non-contact farmers have a very high literacy level (70 %). Literacy in this study is defined as being capable to read and write a small text in English, Arabic or any of the local languages and therefore includes both formal and informal education. This might probably account for the high literacy level reported in this study, which is higher than the national average (30%). When education was disaggregated however, only 48% of the contact farmers and 45% of the non contact farmers had formal schooling. More contact farmers were full time farmers (74.3%) as compared to non contact farmers (57.9%), probably indicating a higher interest of full time farmers in improved IAR technologies.

Level of adoption of IAR improved cassava and sweetpotato technologies. When the IAR improved cassava and sweetpotato technologies were disaggregated, it was discovered that the majority of the respondents who reported using the technologies were more interested in the varieties (62,5%), recommended time of planting (39.2%) and recommended land preparation methods (37.5%). The other aspects such as spacing, fertilizer application, weed and pest management, etc. were not widely used (Table 2). The perceived superior quality of IAR improved cassava and sweetpotato varieties by contact farmers might explain their widespread use. The respondents reported combining improved varieties and their traditional farming practices. The unavailability of the necessary

resources and lack of knowledge (especially for non contact farmers) were some of the reasons given by respondents regarding this combination.

Rate of adoption of improved IAR cassava and sweetpotato varieties. Sanginga *et al* (1999) has shown that estimating the rate of adoption is very important in evaluating technologies. Adoption in this study is defined as the proportion of farmers who had used improved varieties of cassava and sweetpotatoes for at least three consecutive years and were willing to continue using them. Table 3 shows the rates of adoption of improved IAR varieties of cassava and sweetpotato by category of farmer (contact and non contact farmers). Out of the 280 farmers surveyed, 62.5% and 57.1% had adopted improved varieties of sweetpotato and cassava, respectively. However, differences exist in the adoption rates for contact and non- contact farmers. The adoption rates (more than 80%) for contact farmers for both cassava and sweetpotato

were significantly higher than for non contact farmers. This is not surprising because contact farmers play significant roles in the testing, evaluation and dissemination of improved planting materials. More respondents (contact and non-contact farmers) reported using improved planting materials of sweetpotato than cassava. Farmers reported that the lower adoption rate for cassava was due to the fact that improved cassava planting materials are not readily available (especially for non contact farmers) as compared to sweetpotato. This may be due to the low multiplication factor (10) of cassava.

Furthermore, differences exist in the adoption rates across zones (Figure 1). Adoption rates for both cassava and sweetpotato were highest in Njala, followed by Makeni, Bo. Kenema, Rokupr and Kabala. The case of Njala is not surprising since IAR has its headquarters at Njala.

Analysis of the factors determining adoption is essential to discover what category of farmers has benefited from the adoption of improved varieties (Sanginga *et*

Table 2: Farmers' use of improved IAR sweet potato and cassava technologies (%).

Technology	Contact farmer (N = 140)	Non- contact farmer (N = 140)	All farmers (N = 280)
Improved varieties	89.3	35.1	62.5
Land preparation	57.1	21.4	39.2
Time of planting	57.1	17.8	37.5
Spacing	42.9	14.3	28.6
Fertilizer application	28.6	7.1	25
Weed management	39.3	6.4	21.1
Pest management	35.7	5.7	20.7

Table 3: Rate of adoption of improved IAR varieties by category of farmer.

Category of farmer	Proportion of respondents that have adopted improved cassava varieties (%)	Proportion of respondents that have adopted improved sweet potato varieties (%)
Contact farmer	85.7	89.3
Non contact farmer	28.6	35.7
All farmers	57.1	62.5

al., 1999). An analysis of the factors determining adoption was done using a logistic regression model. This model has the ability to handle a binary dependent variable and multiple continuous and categorical variables in an economic analysis. The results of the logistic regression are shown in Table 4. A farmers' age has no influence on the

adoption of IAR improved varieties of cassava and sweetpotato. The negative sign associated with the gender factor suggests that women farmers have a lower adoption probability of the improved varieties than male farmers. Religion has a positive and significant effect. Education does not appear to be a prerequisite for adopting IAR improved

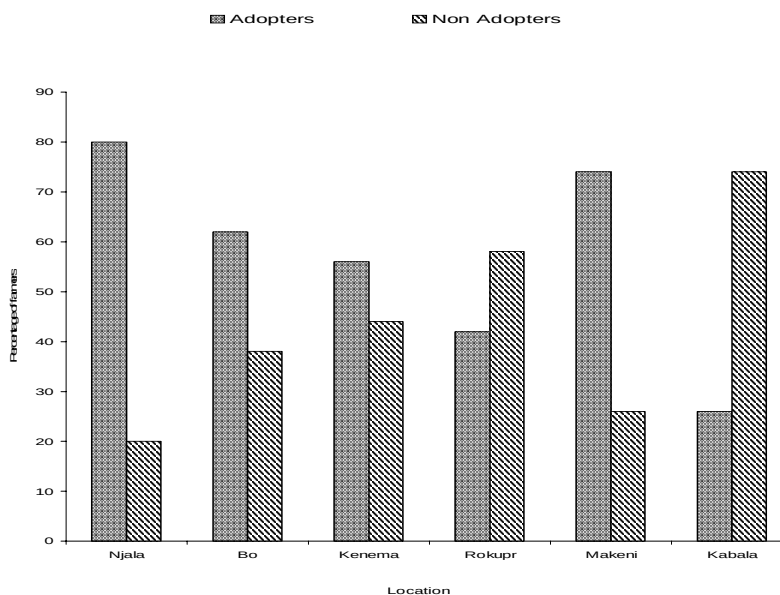


Figure 1: Rate of adoption of improved cassava varieties by zone.

Table 4: An analysis of the socio-economic characteristics determining adoption of improved varieties: Results of Logistic regression.

Explanatory variable	Coefficients
Age	0.011
Gender**, Female =1, male =0	-1.897
Religion, Christian = 1, otherwise = 0	1.042
Literacy, Literate = 1, otherwise = 0	0.280
Marital status**, Married = 1, otherwise = 0	-2.536
Non agricultural income**, Non agriculture income source = 1, otherwise = 0	-1.351
Household size	0.055
Household head, Head of household = 1, Otherwise = 0	-0.099
Land access, access to land = 1, otherwise = 0	-0.618
Labour availability*, Labour available = 1, Otherwise = 0	1.360
Contact farmer**, Contact farmer = 1,) otherwise = 0	3.7590
Years of extension contact	0.030
Constant	2.508

Note: **, * denote significance at 0.01 and 0.05 respectively. Adopt = 1, Non adopt = 0.

varieties of cassava and sweetpotato. Its coefficient in the equation is positive, though not significant. Marital status has a negative and significant coefficient. Being married does not give any advantage in terms of higher probability of adoption.

Farmers who derive part of their income from non agricultural sources are less likely to adopt IAR improved varieties. The coefficient for this variable is therefore negative and highly significant. The household size and being the head of the household appear to have no influence on adoption. Access to land is negative but insignificant. The positive and significant labour parameter indicates a positive probability to adopt improved varieties when farmers have access to labour. The high and positive coefficient for being a contact farmer indicates that contact farmers are more likely to adopt improved IAR varieties as compared to non contact farmers. Farmers' years of extension contact was surprisingly found to have no effect on the probability of adoption. Sangiga *et al.* (1999) and Lahai (1997) also discovered similar results. Although extension services might help farmers to be more aware of innovations in general, the extension services considered in this research constitute IAR extension staff and those of the Ministry of Agriculture, Forestry and Food Security and NGO's. The Ministry and NGO extension services might have little or

no effect on the adoption of IAR improved varieties.

Constraints to farmers' adoption of IAR improved varieties of cassava and sweetpotato.

Farmers' willingness to adopt new technologies is largely a function of available resources. Table 5 shows that more than 80% of contact and non contact farmers reported that limited finance, limited availability of high yielding and disease-free planting materials acceptable by both the producers and consumers and labour shortage were major constraints. Of the three constraints, however, limited finance was considered to be the major constraint when all the farmers are aggregated. This might not be unconnected with the fact that finance is necessary for buying all other farm inputs. More than 70% of contact and non contact farmers considered the unavailability of tools as a serious problem. This might be associated with the loss of tools and other productive resources by farmers during the war. Food shortage was another constraint experienced by 69.1% of contact farmers and 72.1% of non contact farmers. This is a situation that might have been aggravated by the war as farmers had to depend on donor agencies for "food for work" as well as planting materials. 67.9% of farmers considered limited availability of improved planting materials and unavailability of fertilizer to be problems but few (18.6% of

Table 5: Constraints to cassava production identified by respondents (%).

Constraint	Contact farmers (N = 140)	Non contact farmers (N = 140)	All farmers (N = 280)
Finance	82.1	90.0	86.1
Limited availability of improved planting materials	81.4	88.5	85.0
Labour shortage	87.9	81.4	84.6
Land accessibility	18.6	12.1	15.4
Food shortage	69.3	72.1	70.7
Unavailability of fertilizer	67.9	67.9	67.9
Unavailability of tools	79.3	79.3	79.6

Figures do not add up to 100 because some respondents gave multiple responses.

contact farmers and 15.4% of non contact farmers) felt that land accessibility was a problem.

Conclusion

This paper examined the determinants of farmers' adoption of IAR improved varieties of cassava and sweetpotato. From the results of the study, it is apparent that the IAR improved cassava and sweetpotato technology that was readily adopted by farmers was the improved varieties, with more of the contact farmers adopting the improved varieties than non contact farmers. However, Wortmann *et al.* (1997) warned against the pitfalls of making wider inferences from the adoption behaviour of trial farmers, since the experimental process itself may influence the adoption process. Differences also exist in the adoption rates according to the crop and zone. Sweetpotato had a higher adoption rate as compared to cassava and Njala zone (IAR headquarters) had the highest adoption rate followed by Bo. Kenema, Rokupr and Kabala. The results however indicate that among other constraints, the adoption of the improved varieties is inhibited considerably by limited finance and lack of high yielding and disease-free planting materials acceptable by both the producers and consumers.

The findings further suggest that the sex of the farmer, religion, marital status, income sources outside agriculture and being a contact farmer are very important in explaining the adoption or non-adoption of IAR improved varieties of cassava and sweetpotato by farmers. Labour availability is also significant but the age of the farmer, literacy level, household size, household head, access to land and years of extension contact were found not to be significant in explaining the adoption behaviour of the respondents.

Implications. The findings discussed above should have important implications for tropical root and tuber crop production. The

fact that root and tuber crops contribute greatly to food and nutrition security, suggests that research and development agencies concerned with the promotion of tropical root crops production should consider farmer' specific situations, constraints and socio economic characteristics in planning and developing programmes for intervention.

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Influence of the initial moisture contents on the functional and sensory qualities of dried *fufu*

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Abstract. The influence of different initial moisture content on the functional and sensory qualities of dried *fufu* was investigated. The properties used were pH, total titratable acidity, water absorption index, water binding capacity, dispersibility, amylose, and pasting as well as sensory qualities. The influence of different initial moisture content on acidity, water binding capacity, dispersibility and amylose content were not significant, except for water binding capacity and water absorption index, which ranged from 127.8% to 130.8% and 109% to 162.6% respectively. All the samples attained peak viscosity at almost the same time and formed paste at the same temperature (74.8°C). The peak viscosity and final viscosity ranged between 669.8 and 705.8 RVU and 467.2 and 518.9 RVU, respectively. The breakdown viscosity and setback viscosity ranged from 276.5 RVU – 290.5 RVU and 87.9 RVU – 91.0 RVU, respectively. There was significant differences ($P < 0.05$) in the panelist rating of all the sensory qualities (colour, odour, texture and overall acceptability) of the *fufu* dough prepared from *fufu* flour with different moisture content. *Fufu* flours made from wet mass with initial moisture content of 50% results in a more attractive cooked *fufu* dough and was rated highest in all the sensory qualities (especially texture).

Introduction

Fufu is a fermented wet-paste from cassava (*Manihot esculenta* Crantz) (Oyewole and Sanni, 1995) which is an important staple food in West Africa and as well as many parts of

the tropics (Sanni, 1999). *Fufu* is traditionally sold in the wet form (moisture about 50%), which renders it highly perishable. The poor shelf life of *fufu* is a serious limitation for large-scale processors.

A practical approach to improving the shelf life and marketability of *fufu* could be by drying (Okpokiri *et al.*, 1985; Akingbala *et al.*, 1991; Sanni *et al.*, 1998). *Fufu* has also been dried using different methods like sun drying, rotary and cabinet drying. Drying methods did not appreciably affect the properties tested but affected the pasting properties. There was an element of stickiness in the dried *fufu* (Sanni and Akingbala, 2000).

However, being an intermediate moisture food, wet *fufu* that has high initial moisture content before drying is prone to starch damage that may affect its texture and then acceptability by the *fufu* eaters. This project therefore reports findings on the influence of the initial moisture contents on the qualities of dried *fufu*.

Materials and Methods

Cassava sample. Freshly harvested cassava (low cyanide variety, TMS 30572) was obtained from the University of Agriculture Abeokuta farm. Roots were harvested after about 11 – 12 months after planting.

Preparation of wet *fufu*. Methods described by Oyewole and Sanni (1995) were employed in preparing *fufu*. Cassava roots were peeled, washed, and cut into 4 - 5cm thick pieces and soaked in water and kept at room temperature ($28 \pm 3^\circ\text{C}$) for 72 h. The fermented cassava

roots were mashed and sieved manually. The throughs were allowed to sediment for 24h before the meshes were load pressed in a synthetic sack until moisture levels of 50, 62 and 83% (wb) were obtained.

Preparation of dried *fufu*. Mashers (500g each) of wet *fufu* were dried in a cabinet drier (Model LEEC F2) according to Sanni and Akingbala (2000). The cabinet dryer consists of an insulated chamber fitted with perforated trays. Hot air was circulated through the cabinet at 3m/s per square meter tray area. A system of duct and baffles was used to direct air over and through each tray to promote uniform air distribution. The drying temperature was 65°C for 7h with a loading density of 5.3kg/m². *Fufu* flours (60 mesh size) were obtained by crushing the balls using a wooden source on a polished surface to reduce friction hence reducing starch granule damage by milling.

pH. Five gram of flour samples (60 mesh size) were thoroughly mixed with 25 ml of distilled water for 5 min. at 30°C and allowed to stand for 1 min. Sample pH was then measured using an electronic pH meter (Kenteil 7020, Japan) (Sanni, 1999). Determinations were made in triplicate.

Total titratable acidity (TTA). Fresh mash and flour samples were extracted with distilled water at a ratio of 1:5 (flour: water) and thoroughly mixed for 5 min. 10 ml of the extracted solution was titrated with 0.1N NaOH using phenolphthalein indicator solution according to Sanni (1999). The TTA was expressed as % (w/v). Determinations were made in triplicate. $1 \text{ ml } 0.1\text{N} \leq 0.009 \text{ g lactic acid}$.

Water Absorption Index (WAI). A modified method of Ruales *et al.* (1993) was employed. 2.5g of *fufu* flour were weighed into a tarred centrifuge tube. 30ml of distilled water at 30°C was added and mixed properly. The slurry was stirred intermittently for 30 minutes and centrifuged at 9,500 rpm on SPECTRA, U.K., Merlin 503 centrifuge for 10 minutes. The

supernatant was then discarded and the centrifuge tube inverted and allowed to drain for 10 minutes. The remaining gel was then weighed.

Water Absorption Index (WAI) % = Grams bound water x 100/2.5.

Dispersibility. This was determined by the method described by Kulkarni *et al.* (1991). 10g of the *fufu* powder were weighed into 100ml measuring cylinder and distilled water added to make a volume of 100ml. The set up was stirred vigorously and allowed to settle for three hours. The volume of the settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

Amylose. A rapid calorimetric method for estimating amylose content of starches and flour described by Williams *et al.* (1970) was employed. An aliquot of the starch solution was put into a 50ml volumetric flask with addition of 5ml of 0.1N HCl and 0.5ml of iodine reagent. The volume was diluted to 50ml and the absorbance measured at 620nm after 5 minutes. The analyses were made in triplicate.

Pasting properties. Pasting properties were determined with a Rapid Visco Analyser according to IITA (2001). The temperature was raised at 1.5°C/minutes from 30°C to 95°C and kept at 95°C for 30 minutes and then cooled to 50°C at the same rate. Pasting properties was read from the viscograph.

Sensory qualities evaluation. Taste panel evaluations of dried *fufu* samples were assessed using a panel of 50 tasters who were *fufu* eaters (Sanni and Jaji, 2003). *Fufu* was cooked in boiling water at a ratio of 2:3 (flour: water). The panels were asked to score for sensory attributes as taste, texture, appearance, odour and overall acceptability using a 9-point hedonic scale, where 1 and 9 represent dislike extremely and like extremely, respectively. Responses of the panelists were subjected to statistical analysis of variance

and means separated by Duncan's Multiple Range Test to establish if there were significant sample effects (Larmond, 1977).

Results and Discussion

Acidity and functional properties of dried *fufu* of different initial moisture contents.

The acidity and functional properties of dried *fufu* produced from initial moisture contents of 83%, 62% and 50% (wb) before drying is presented in Table 1. The pH ranged between 4.37 and 4.34 while the value of the total acidity ranged from 0.03 and 0.04. There was no marked difference in the pH and acidity values of the dried *fufu* from the different samples. The values of Water binding capacity and Water absorption index ranged between 127.8% and 130.8%, and 109% and 162.6%, respectively. The values increased with increase in the moisture content of the wet mass. The extent of modification of starch properties is related to water absorption capacity and water absorption index (Shittu *et al.*, 2001). A damaged starch granule has surface defect(s) through which water molecules escape into its internal parts. This causes it to absorb more water and is susceptible to enzyme degradation than an undamaged starch (Tipples, 1969). Hence, high initial moisture content wet *fufu* mass will probably gives a flour with more damaged structure and lower shelf-life as a result of high water absorption capacity and water absorption index (Table 1) (Tipples, 1969).

Percentage dispersibility value ranged from 64% - 67%. *Fufu* flour from a sample

initially with 58% moisture content had the lowest 83% initial moisture content, while that from a sample had the highest moisture content. Dispersibility is a measure of the reconstitutability of flours or blends in water. The higher the dispersibility, the better the flour reconstitutes in water (Kulkarni *et al.*, 1991). Hence, high initial moisture content wet mass results into flour that easily reconstitutes in water (Table 1). However, the values of dispersibility of the flour from different initial moisture content were very close.

The amylose content of *fufu* flours ranged between 71.7% and 72.0% and were not significant ($P>0.05$) (Table 1).

Pasting properties of *fufu* flours of different initial moisture contents.

The commonest parameter used to estimate the functional properties of starch-based products is amylographic-pasting properties (Ruales *et al.*, 1993). *Fufu* flour forms paste when cooked, hence, its pasting properties are important in predicting the behaviour of its cooked paste. All the samples give similar pasting temperature of 74.8°C (Table 2). The time to reach peak viscosity by the samples ranged from 5.0 – 5.1 minutes. *Fufu* sample with initial moisture content of 50% (wb) had the lowest peak viscosity of 669.8 RVU, showing lower starch granular disruption. While *fufu* flour from wet mass of 80% initial moisture content had the highest peak viscosity of 705.8 RVU. But the extent of retrogradation on cooling as shown by the setback value was more pronounced in the *fufu* flour from wet mass with initial moisture content of 60% and was

Table 1: Acidity and functional properties of dried *fufu* of different initial moisture contents.

Properties	<i>Fufu</i> (mc: 50%, wb)	<i>Fufu</i> (mc: 62%, wb)	<i>Fufu</i> (mc:83%, wb)
pH	4.37a	4.34a	4.34a
Total titratable acidity (% Lactic acid)	0.03a	0.04a	0.03a
Water binding capacity (%)	127.8a	130.6b	130.8b
Water absorption index (%)	109c	146.8b	162.6a
Dispersibility(%)	64a	66a	67a
Amylose(%)	71.7a	72.0a	72.0a

Mean scores in each row followed by the same letters are not significantly different ($P > 0.05$).

least in the *fufu* flour from wet mass with initial moisture content of 50% (Table 2). Since setback value indicates the tendency of paste to undergo retrogradation, this is an indication of high retrogradation tendencies for *fufu*-wet mass with higher initial moisture content before drying. Setback also has a serious implication on the digestibility of starch pastes when consumed (Shittu *et al.*, 2001). Higher setback values may result in reduced paste digestibility. *Fufu* flour prepared from wet mass with lower initial moisture content is least prone to this effect (Shittu *et al.*, 2001) as it had the lowest setback value.

Sensory qualities of cooked *fufu* flours of different initial moisture contents. Table 3 shows the mean scores of sensory qualities of cooked *fufu* samples from flours prepared from wet mass having different initial moisture content. There were significant differences ($P < 0.05$) in the panelist ratings for all the sensory attributes (colour, taste, texture, aroma and overall acceptability). *Fufu* flour made from wet mass with initial moisture content of 50% was more attractive and acceptable than the rest of the *fufu* samples (Table 3). In terms of texture, the panelist rated

cooked *fufu* samples from wet mass with 50% initial moisture content highest. A strong negative correlation existed between sensory texture and peak viscosity, final viscosity, or setback value while a positive correlation existed between sensory texture and breakdown (Table 4). This implies that the lower the peak viscosity, final viscosity, or setback value, the better the sensory texture of cooked *fufu* and vice versa, but the higher the value of setback, the higher the textural quality of cooked *fufu*.

Conclusion

This work has revealed that there was no remarkable effect of the initial moisture content of wet *fufu* before drying on the pH, total titratable acidity, dispersibility and amylose content as well as time to attain peak viscosity and pasting temperature. However, in terms of water absorption index, water-binding capacity, pasting viscosities and sensory attributes (colour, odour, texture and overall acceptability), there were significant differences in the dried *fufu* from different initial moisture content prior to drying. Cooked *fufu* from flour produced from wet mass with 50%

Table 2: Pasting properties of dried *fufu* of different initial moisture contents.

Properties	<i>Fufu</i> (mc:50%, wb)	<i>Fufu</i> (mc: 60%, wb)	<i>Fufu</i> (mc: 80%, wb)
Pasting Temp (°C)	74.8	74.8	74.8
Peak Viscosity (RVU)	669.8	670.7	705.8
Peak time (min)	5.1	5.0	5.1
Breakdown (RVU)	290.5	290.3	276.5
Final viscosity (RVU)	467.2	471.3	518.9
Set back value (RVU)	87.9	91.0	89.6

Table 3: Sensory qualities of dried *fufu* of different initial moisture contents.

Samples	Colour	Odour	Texture	Overall acceptability
<i>Fufu</i> (Mc: 50%, wb)	6.7a	7.0a	7.7a	7.2a
<i>Fufu</i> (Mc: 60%, wb)	6.3a	6.2b	5.8b	6.1b
<i>Fufu</i> (Mc: 80%, wb)	5.9ab	5.8b	5.5b	5.1c

Mean scores in each column followed by the same letters are not significantly different ($P > 0.05$).

Table 4: Pearson's correlation matrix between functional, pasting and sensory properties of dried *fufu* from wet mass with different moisture content.

	Peak viscosity	Peak time	Breakdown	Final viscosity	Setback value	Water absorption capacity	Water absorption index	Dispersibility	Amylose	Colour	Odour	Texture	Overall acceptability
Peak viscosity	1.000												
Peak time	.481	1.000											
Breakdown	-1.000**	-.489	1.000										
Final viscosity	.999**	.437	-.998*	1.000									
Setback value	.078	-.837	-.068	.127	1.000								
Water absorption capacity	.569	-.447	-.561	.609	.864	1.000							
Water absorption Index	.742	-.231	-.736	.774	.726	.973	1.000						
Dispersibility	.770	-.189	-.764	.801	.696	.963	.999	1.000					
Amylose	.519	-.500	-.511	.561	.893	.998*	.958	.945	1.000				
Colour	-.877	.000	.872	-.899	-.548	-.894	-.973	-.982	-.866	1.000			
Odour	-.770	.189	.764	-.801	-.696	-.963	-.999*	-1.000*	-.945	.982	1.000		
Texture	-.622	.387	.615	-.660	-.829	-.998*	-.986	-.979	-.992	.922	.979	1.000	
Overall acceptability	-.863	.027	.858	-.887	-.570	-.906	-.979	-.987	-.879	1.000*	.987	.932	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

initial moisture content was more attractive and acceptable by the sensory panelists. Therefore, wet *fufu* with initial moisture content of 50% gives a dried *fufu* with acceptable textural property and reduced stickiness. Thus, *fufu* processors are advised to express out more water before loading wet *fufu* for drying.

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Production of instant cassava noodles

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Abstract. To increase the utilization of composite flours from cassava, soybean and wheat, this paper report findings on the chemical and sensory qualities of instant noodles from cassava, soybean and wheat. Flour from cassava, wheat and soybean were used in different formulations (90:7.5:2.5; 80:15:5; 70:27.5:7.5, 60:30:10; 100:0:0; and 0:100:0 to cassava–wheat–soybean) to produce instant noodles. Chemical and sensory properties of the instant cassava-wheat-soybean samples were analyzed. The result obtained from the proximate analysis showed that increase in percentage of cassava in the noodle sample increased the carbohydrate, ash and fibre content, respectively. There were significant differences ($P<0.05$) in the sensory attributes (color, aroma, appearance, flavor, taste and texture) of the instant cassava-wheat-soybean samples. Statistically ($p<0.05$), noodles produced from 100% wheat flour were the most acceptable by the panelists, closely followed by those made from 60% cassava, 30% wheat, 10% soybean; and, 70% cassava, 27.5% wheat, 7.5% soybean, respectively.

Introduction

Noodles are long thin piece of food made from a mixture of flour, water and eggs usually cooked in soup or boiling water (Longman, 2000). They are a form of staple food very popular among the Asians (Kit Chan, 2002). It is also a quick cooking pasta that can be prepared in a microwave or by immersion in

hot water for 2-3 minutes (Matz, 1991). They can be made either by hand or by machine. They are divided into “cut noodles” or “dried noodles” depending on how they are made. Made in whatever way, they may be of different width varying from ribbons to threads. As a prepared dish, they can be served warm or cold dressed with chili oil or not, eaten with fried bean sauce, pork or chicken sauce, duck chops and soup of any concoction.

Pasta is an ancient food stuff which could be defined as a type of dough extruded or stamped into various shapes for cooking. Pasta is economical, easy to prepare, have longer shelf life, and are consumed all over the world in many different ways. Pasta products are normally made from amber durum wheat which is milled into semolina and mixed with water, salt, eggs, vegetable oil, and a times vegetable coloring. Semolina is preferred to flour because less water is required to make the pasta dough, which greatly helps in the drying stage (Bernard Davis, 1988). The variety of products from pasta has increased in part through the addition of vegetable materials which provides different flavors, color and often additional nutrients (Matsuo *et. al.*, 1975; Banasik, 1975). Recently, research into processing of pasta that eliminates the need for cooking for a very longtime has resulted in the production of instant noodle snacks (Kim, 1996). There is also a variety of “Instant Noodles”, which are precooked, dried and commercially packed. These are simply soaked in hot boiling water for a few minutes before they are eaten.

During the ban on the importation of wheat flour to Nigeria in 1987 for bread and other baked products, most baking industries had to close down while many bakeries had to adopt alternative solutions to stay in business (Chris, 1987). One of the solutions developed was the mixing and using of flour from other sources into wheat (Osuntogun, 1987). “Composite flour” is the name given to wheat that has been diluted with other non wheat materials like cassava, maize, and soybean. Several investigators have studied the use of composite flour in bread making (Ogunsua and Hudson, 1976; Nout, 1977; Kim *et al.*, 1978). Non wheat materials like in composite flour reduce the cost of production of bread and other baked products. To increase the utilization of composite flours from cassava, soybean and wheat. The aim of this project was to investigate the chemical and sensory qualities of instant noodles from cassava, soybean and wheat. This information is important for improving these products and therefore increasing the utilisation of composite flour.

Materials and Methods

Freshly harvested twelve months old cassava roots (TMS, 30572 variety) were obtained from the University of Agriculture, Abeokuta, farm. Also wheat flour, soybeans and lesieur

pure vegetable oil were purchased from Osiele market in Abeokuta, Nigeria. Tartrazine, iodized salt, guar gum, sodium polyphosphate and calcium carbonate were bought from Kuto Market, Abeokuta, Nigeria.

Cassava flour preparation. The cassava roots were processed immediately on arrival at the laboratory. The roots were washed, peeled, grated, pressed/dewatered, dried (65°C for 24hrs), milled and sieved (0.05mm).

Soybean flour preparation. Soybean was processed immediately on arrival at the laboratory. The soybean was sorted cleaned, blanched (20min in H₂O), soaked (6h), dehulled, dried (65°C for 7h), milled and sieved.

Instant noodle ingredient formulation. The ingredient formulations used in this study are presented in Table 1.

Production of instant cassava – wheat – soya noodles. All the ingredients were weighed out in the right proportions. The alkali mixture i.e. guar gum, iodized salt, tartrazine, sodium phosphate, potassium carbonate and the appropriate amount of water were first mixed in a mixer with constant stirring for about 20minutes, they were added one after the other to prevent formation of lumps. After this, the pH was tested to ensure that it ranged from

Table 1: Ingredient formulation for instant cassava – wheat – soybean noodles (percentage composition).

Ingredients	Sample (%)					
	CWS ₁	CWS ₂	CWS ₃	CWS ₄	CWS ₅	CWS ₆
Cassava flour	78.59	69.86	61.13	52.40	87.33	0
Wheat flour	6.55	13.10	19.64	26.20	0	87.33
Soybean flour	2.18	4.37	6.55	8.73	0	0
Guar gum	4.41	4.41	4.41	4.41	4.41	4.41
Iodize salt	5.24	5.24	5.24	5.24	5.24	5.24
Sodium phosphate	1.81	1.81	1.81	1.81	1.81	1.81
Potassium Carbonate	1.18	1.18	1.18	1.18	1.18	1.18
Tartrazine	0.02	0.02	0.02	0.02	0.02	0.02
Water	0.03	0.03	0.03	0.03	0.03	0.03

The cassava:wheat:soybeans ratio = CWS₁ = 90:7.5:2.5; CWS₂ = 80:15:5; CWS₃ = 70:27.5:7.5; CWS₄ = 60: 30:10; CWS₅ = 100:0:0; CWS₆ = 0:100:0.

10 -11. The mixture of cassava, wheat and soybean flour weighed were introduced into the mixer and the alkali mixture added in a stepwise manner in a Kenwood Mixer (Model No. Km 120mm, Kenwood limited UK). The mixer was set at higher speed for 10minutes to allow thorough mixing and softening of the dough. The dough formed was kneaded with a rolling pin to form a sheet. The sheet was then moved to the kneading section of the Marcato paster bike machine (Model No. 150mm, ATLAS, Italy) for further kneading before moving to the slitting section of the same machine where the slitter cuts the kneaded dough into strands 1.00 – 1.05mm thick each. The slitted dough was then steamed for about 2 – 4min before frying in an automatic deep fryer for about 2 minutes at the temperature of 170°C. The fried products were removed and allowed to cool and then packaged.

Cooking time determination of instant cassava-wheat- soybean noodles. The instant noodles were cooked separately by immersion in boiling water and thereafter allowed to stay for few minutes. The different times taken for each of the samples to cook were recorded.

Proximate analysis: Moisture content determination. The moisture content of cassava-wheat-soybean noodle was determined using the AOAC method (1990). Five grammes of ground samples were weighed and put in desiccators to cool. After cooling the ground samples was weighed and returned to the oven for 30minutes, cooled and weighed again. The process was repeated until constant weight was obtained. The percentage moisture content was then calculated.

Crude protein determination. Crude protein was determined by the AOAC methods (AOAC, 1990) carried out using the automated semi micro Kjeldahl method. 0.2g of samples plus 0.8g of the digestive mixture plus 10ml of concentrated H₂SO₄ were gently heated in the fuming chamber until digest was clear. The

cooled digest was transferred to a 100ml volumetric flask and quantitatively diluted to the mark. 10ml of digested solution plus 15ml of NaOH and 15ml Na₂SO₃ were distilled. The distillate was collected and 10ml of boric acid with screen methyl red as an indicator and titrated with 0.1N hydrochloric acid. Crude protein was determined from %N as shown:

$$\% \text{ Nitrogen} = \frac{(\text{titre} - \text{blank}) \times \text{Nacid} \times 1.4}{\text{Weight of sample}}$$

$$\% \text{ Nitrogen Protein} = \% \text{ Total Nitrogen} \times 6.25$$

Crude fat. Crude fat was determined by the method of AOAC (1990). The extraction flask was dried to a constant weight and recorded. Ground samples (5g) were accurately weighed into a filter paper, wrapped properly and placed in a thimble and transferred to the extraction barrel N-hexane that was enough to run through the duration of extraction flask. During extraction the water inlet tap remained opened and flask was heated on the regulated heating mantle for 3 hours at a condensation rate or at least 3-6 drops per second.

After extraction time was completed, the thimble was removed from the extractor barrel and distillation was continued until the estimation flask was almost dry. The flask now containing oil was detached and dried in the oven over night at 70°C to constant weight. The thimble was then removed from the oven, cool in a desiccator and weighed. Crude fat was determined as:

$$\text{Crude fat (ether extract) \%} = \frac{W_2 - W_3}{W_1} \times 100$$

W₁ = weight of sample

W₂ = weight of flask before extraction

W₃ = weight of flask plus oil after extractor

Determination of ash content. Ash content was determined according to AOAC (1990). Two grammes of the ground sample was accurately weighed into a dish. The samples were ignited on a hot plate in a fume cupboard to get rid of the organic matter. The dishes were then placed in the muffle furnace. They

were then transferred to a desecrator, cooled and weighed immediately. Ash content (%) was determined as:

$$\text{Ash content (\%)} = \frac{\text{Weight of Ash} \times 100}{\text{Weight of dry sample}}$$

Crude fibre determination. Crude fibre was determined following method described by Pearson (1991). 1g of ground sample was weight into the digestion flask and 100ml or TCA digestion reagent was added. This was placed on the heating unit of digester and the water supply to reflux condenser was opened. It was brought to boiling and refluxed for exactly 40minutes counting from the time boiling commenced. The flask was then removed from the heater, cooked a little and filter through No. 4 (15.0cm diameter). The residue was washed six times with distilled water and once with industrial spirit and then transferred to a previously ignited and pre-weighed dish dried overnight in an oven at 105°C, transferred to desiccators and weighed when cool. This was then ash in a muffle furnace 600°C for 6 hours, allowed to cool and re-weighed. Fibre content was determined as:

$$\% \text{ fibre} = \frac{\text{Loss in weight on ashing} \times 100}{\text{Weight of sample}}$$

Total carbohydrate determination. This was determined according to AOAC (1990). It was determined as a difference between 100 and total sum of the percentages of fat, protein, moisture, ash and crude fibre.

Chemical analysis: determination of free fatty acid. Free fatty acid was determined according to Pearson, 1991. Ten grammes of oil (i.e. 11ml) was weighed and placed in a 250ml Erlenmeyer flask and dissolved in 50ml neutral diethyether/ethanol mixture and 0.5ml of phenolphthalein indicator, added, and then titrated against 0.1N NaOH to a pink color as the end point.

$$\text{Free fatty acid} = \frac{\text{Titration (ml)} \times 5.61}{\text{Weight of sample used}}$$

Determination of peroxide value. The peroxide value was determined by the Pearson (1991) method. Two and half grammes of oil was weighed into 250ml conical flask with grounded naked glass stopped 30ml of acetic acid – chloroform solution, was added, the flask was swirled until the sample was dissolved in the solution. 1ml saturated solution of iodide (KI) was added, the solution was swirled again for 1minute and then 30ml of distilled water was added, mixed thoroughly and then stored in a dark cupboard for 30minutes. After 30 minute the solutions was then titrated with 0.1N $\text{Na}_2\text{S}_2\text{O}_3$ solution with starch as indicator to the yellow color of the solution to blue black. Peroxide value was calculated as:

$$\text{Peroxide value} = \frac{(v_a - v_b) \times 100 (\text{mg equivalent}/100\text{g})}{\text{Weight of sample}}$$

V_a = vol. of $\text{Na}_2\text{S}_2\text{O}_3$ solution for sample titration (ml)

V_b = vol. of $\text{Na}_2\text{S}_2\text{O}_3$ solution for blank titration (ml)

N = Normality of 0.01 $\text{Na}_2\text{S}_2\text{O}_3$ solution

W = weight of sample (g)

Sensory evaluation. A taste panel of cooked noodles prepared from various formulations was conducted, using a panel of 30 judges; who were regular noodles eaters. The judges were asked to score for color, flavor, taste, texture and appearance using a 9 point hedonic scale; where 1 and 9 represent dislike extremely and like extremely respectively.

Statistical analysis. All data were subjected to analysis of variance [ANOVA] using SPSS [Version 10.2, 2002] statistical package. Means were separated with Duncan Multiple Range Test (DMRT). Pearson's correlation matrix was determined between the results of chemical composition of all the noodles using the same statistical package.

Results and Discussion

Proximate composition of instant cassava-wheat-soybean noodles. Table 2 presents the proximate composition of instant cassava-noodles. The moisture content of the noodle samples ranged from 2.1 to 3.7, with noodle sample CWS₂ (Cassava-wheat-soybean in the ratio 80:15:5) having the highest moisture content of 3.7. There are no significant difference between the moisture content of the noodle sample at ($P>0.05$). The values were within expected moisture level according to Enwere (1998).

Generally, there were significant differences ($P<0.05$) in the carbohydrate, protein, fat, ash and fibre contents of the noodle samples. The carbohydrate content of these noodle sample ranged from 64.7 to 79.7. The noodle samples CWS₅ (cassava-wheat- soybean in the ratio 0:100:0) had the highest carbohydrate content of 79.7 while the noodle sample CWS₆ (cassava- wheat-soybean in the ratio 100:0:0) had the lowest CHO content. This may be as a result of the high contents of carbohydrate in cassava flour (Oguntona and Akinyele, 1995). The percentage protein content of the instant noodles ranged from 5.8 to 12.1. The noodle sample CWS₆ had the highest protein content while the noodle sample CWS₅ had the lowest protein content. This is attributed to the high protein content in wheat and soybeans (Enwere, 1998). The fat content ranges from 11.1 to 18.4 with noodle sample CWS₆ having the highest fat content and sample CWS₅ the

lowest. This may be as a result of the absorption of the fat during frying. The ash content ranged from 0.7 to 1.2 with noodle sample CWS₅ having the highest ash content and noodle sample CWS₂ with lowest. This is attributed to the high percentage of ash in cassava. The fibre content ranged from 0.2 to 0.8 with noodle sample CWS₆ having the highest fibre content most probably due to high fibre in cassava (FAO, 1972).

Chemical composition of the instant cassava-wheat-soybeans noodle. The free fatty acid and peroxide values for cassava-noodles are presented in Table 3. The FFA values ranged from 0.3 to 0.5 with CWS₅ recording the highest. The free fatty acid is a measure of the extent to which the glycerides in the oil have been decomposed by lipase or other action (Pearsons, 1991). Rancidity is accompanied by free fatty acid formation i.e. spoilage of the oil and is used as a condition for the edibility. The higher the FFA value, the more prone the oil is to spoilage.

The peroxide value ranged from 4.0 to 6.2 with CWS₅ recording the highest value. There were no significant differences between the noodle samples at ($P>0.05$). The peroxide value is a measure of the peroxides contained in the oil. During storage, peroxide formation is slow at first but latter increases. This shows that the more the peroxide value the higher the rate at which the oil decomposes, thereby leading to the spoilage of the sample. From our results, the peroxide values are low in comparison to the minimum values reported

Table 2: Proximate composition of instant cassava – wheat – soybean noodles.

Sample code	Ash %	Cho %	Fat %	Moisture %	Fibre %	Protein %
CSW ₁ =148	0.9ab	72.0a	15.9bc	3.6a	0.7b	6.9bc
CSW ₂ =213	0.6b	72.0a	16.5bc	3.7a	0.5c	7.2b
CSW ₃ =317	0.9ab	70.3a	16.8b	3.7a	0.5c	8.0b
CSW ₄ =425	0.7b	71.0a	17.2b	2.5a	0.4c	8.4b
CSW ₅ =579	1.2a	79.1a	11.1d	2.1a	0.8a	5.8c
CSW ₆ =614	0.9ab	64.6b	18.4a	3.5a	0.2d	12.4a

Mean values followed with different alphabet within column are significantly different ($p<0.05$).

previous by authors (Pearsons, 1991). Therefore, the noodle sample can be stored for a very long time without getting spoiled.

Correlation matrix of proximate and chemical properties. Table 4 presents Pearson's correlation matrix of proximate composition and chemical properties of instant cassava-wheat – soybeans noodles. From the result, the carbohydrate content of the instant noodle samples correlates inversely with its moisture, fat and protein content, respectively. The carbohydrate content also correlates positively with fibre content. The peroxide value does not correlate with any of the proximate values while FFA correlates inversely with the fat, fibre and carbohydrate contents.

Sensory qualities of noodles. The result of the sensory evaluation of instant cassava-

wheat-soybean noodles are shown in Table 5. In terms of appearance, aroma, color, flavor and texture, noodle sample 614 (cassava-wheat- soybean in the ratio 0:100:0) was the most acceptable. Sample 579 (cassava-wheat- soybean in the ratio 100:0:0) was the least acceptable. In terms of taste, noodle sample 614 was the best noodle samples 148 and 579 the worst. Overall, sample 614 (cassava- wheat- soybean in the ratio 0:100:0) was the best. This might be due to the presence of high cassava content in the noodle.

Conclusion

From this work, instant noodles produced from composite flour were different from each other. It was observed that as cassava in the noodle samples increased, there was an increase in their carbohydrate and fibre

Table 3: Chemical composition of instant cassava – wheat – soybean noodles.

Sample code	FFA %	Peroxide % (ns)
CSW ₁ =148	0.4b	6.2a
CSW ₂ =213	0.4b	4.2b
CSW ₃ =317	0.3b	5.0a
CSW ₄ =425	0.3b	5.5a
CSW ₅ =579	0.5a	4.0b
CSW ₆ =614	0.3b	4.4b

Mean values followed with different alphabet within column are significantly different (p<0.05).

Table 4: Pearson's correlation matrix of proximate composition and chemical properties of instant cassava- wheat – soybeans noodles.

	Moisture	Ash	Fat	Fibre	Protein	CHO	P-value	FFA
Moisture	1.000							
Ash	-.216	1.000						
Fat	.528	-.599*	1.000					
Fibre	-.261	.398	-.857**	1.000				
Protein	.287	-.220	.707*	-.803*	1.000			
Cho	-.5938	.408	-.925**	.850**	-.892**	1.000		
P-value	-.175	-.276	.204	.072	-.079	-.027	1.000	
FFA	-.164	-0.46	-.594*	.618*	-.431	.537	-.150	1.000

* Significant at p < 0.05. **Significant at p = 0.01.

Table 5: Mean score of sensory evaluation of instant cassava–wheat–soybean noodles.

Sample code	Appearance	Aroma	Colour	Flavour	Taste	Texture	Overall acceptability
CSW ₁ =148	6.2b	6.0b	6.6a	5.6b	4.9c	5.7b	5.5bc
CSW ₂ =213	6.3b	5.9b	6.2a	5.8b	5.9b	5.8b	5.9b
CSW ₃ =317	6.0b	5.8b	6.0a	5.9b	5.9b	5.8b	6.0b
CSW ₄ =425	5.6b	5.9b	5.7b	5.8b	5.6b	6.0b	6.1b
CSW ₅ =579	3.3a	5.2b	3.9c	5.2b	5.0b	5.0b	4.8c
CSW ₆ =614	6.5b	7.1a	6.9a	7.3a	7.4a	7.2a	7.5a

Mean values followed with different alphabet within column are significantly different (p<0.05). n = 30.

content and a decrease in protein and fat content. The noodle sample with 100% wheat was highly accepted closely followed by noodle samples 425 (60:30:10 cassava: wheat: soybean) and 317 (70:27.5:7.5 cassava: wheat: soybean).

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Effect of cassava (*Manihot esculenta*) root meal supplemented with Nile Perch (*Lates niloticus*) fish waste on the rumen environment

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Abstract. The supplementary effect of cassava (*Manihot esculenta*) root meal (CRM) and Nile Perch (*Lates niloticus*) fish waste (FW) on the rumen environment was compared to that hominy meal (HM) and cotton seed cake (CSC). The feed's degradability characteristics and chemical contents, rumen pH and rumen ammonia nitrogen ($\text{NH}_3\text{-N}$) levels in cows fed on four ration combinations (HM + CSC, CRM + CSC; HM + FW and CRM + FW) denoted as T_1 , T_2 , T_3 , T_4 , respectively) were determined. Results showed that DM degradability at 48h for CRM was higher ($P < 0.05$) than that of HM (920 vs 835 g/kg). HM had higher ($P < 0.05$) CP content than CRM (946 vs 837 g/kg) respectively. Both DM and CP contents of CSC were higher ($P < 0.05$) than those of FW (739 and 887 vs 367 and 598 g/kg) respectively. The degradability of DM for the TR_1 and TR_2 rations was higher ($P < 0.05$) than that of TR_3 and TR_4 (801 and 799 vs 727 and 616 g/kg DM respectively. TR_2 had higher ($P < 0.05$) rates of DM degradability than the rest of the rations. The ruminal pH and $\text{NH}_3\text{-N}$ values differed ($P < 0.05$) between treatments. Treatments containing FW (TR_3 and TR_4) had higher ($P < 0.05$) $\text{NH}_3\text{-N}$ than those containing CSC (TR_1 and TR_2) (284.7 and 203.7 vs 135.8, and 183.9 mg/l). It is concluded that CRM when fed in combination with FW gave higher DMD values and provided a better fermentation environment than HM and CSC. It is further concluded that CRM and FW could be good substitutes for HM and CSC as sources of energy and

nitrogen for dairy cattle and other ruminant animals.

Introduction

Poor quality hays are low in energy and protein content, which cannot meet the nutrient requirement of cattle in terms of absorbable amino acids and microbial protein (Preston and Leng 1987; Smith *et al.*, 1991, Shem *et al.*, 1995; Kimambo *et al.*, 1999). Rations balanced for energy and protein are thus necessary to ensure maximum dry matter intake and degradability of and for the creation of optimal rumen environment. According Pham Kim Cuong *et al.* (2001), the rate and extent of fermentation of cell wall carbohydrates in the rumen and their absorption is the major goal of any economic ruminant feeding regime. Fresh cassava root is low in dry matter but rich in energy due to its high content of starch and its high amylopectin content. This makes it a more suitable source of energy for ruminants than maize (Kanjapaputhipong *et al.*, 2001) maize. On the other hand, FW are an excellent source of rumen undegradable protein (RUDP) (Thonney and Hogue, 1986) compared to cotton seed cake, which is good source of rumen degradable protein (RDP). Supplementary rations containing FW have been reported to improve total rumen digestible organic matter (Pham Kim Cuong *et al.*, 2001). Conventional energy and supplement feeds have become very expensive and beyond the purchasing power

of most small-scale livestock producers in Tanzania and have limited supply due to the expanding local demand and from the local and external markets,. That coupled by the huge competition for cereals from human beings necessitates the search for alternative locally available feed resources including cassava root meal (CRM) and Nile fish wastes (FW).

The utilization of CRM and FW livestock feeding is well documented (Pham Kim Cuong *et al.*, 2001; Sammart *et al.*, 2000). They are also abundant and locally available in Tanzania (Katakweba, 2002) and have huge potential to replace cereal and oil seed by-products in livestock feeds in Tanzania. However, the choice of any supplement usually will depend on its availability, cost and its nutritive value (Shem *et al.*, 2003).

The major objective of this study was therefore, to evaluate the nutritive value of CRM, specifically its effects on changes in the rumen environment when supplemented with Nile perch fish wastes.

Materials and Methods

Feeds. The experimental animals were fed on a basal diet of *Chloris gayana* grass hay chopped to approximately 2-3 cm length. Supplemental rations contained CRM, HM, FW, CSC and minerals of different proportions. Fresh cassava was purchased from farmers in villages in Morogoro rural district while FW was obtained from the numerous fish processing factories around

Mwanza City on the shores of Lake Victoria. The unpeeled fresh cassava roots were washed with clean water to remove the soil, chopped by hand into small slices and sun dried for three days to reduce HCN from 863 to 90.5 mg/kg DM (Bui Van Chinh and Le Viet Ly, 2001). It was then packed, weighed and stored under moisture free conditions. Hominy meal, cotton seed cake and minerals were purchased from feed stores in Morogoro town.

Treatments and experimental design. The four treatment rations used in the experiment are as shown in Table 1. Treatment 1 (TR₁) was composed of hay, CRM and HM. Treatment 2 (TR₂) contained hay, CSC and CRM; treatment 3 (TR₃) included hay, FW and HM and treatment 4 (TR₄) contained hay, FW and CRM in a 4 x 4 (four animals x four treatments) Latin square design experiment using fistulated Friesian-Zebu crossbreed cows (314 ± 25kg liveweight) in four periods.

Experimental animals and their management.

Prior to commencement of the experiment the animals were dewormed using Levamisole injectable solution (1ml/10kg live weight) (Hoonspraten Ltd Belgium) and supplied with multivitamins at the rate of (1ml/10kg live weight) (Hoonspraten Ltd Belgium). To control ectoparasites, a pour on acaricide (pyrethrins) (Coopers Ltd, Nairobi Kenya) at the rate of (1ml/20kg live weight) was used. The cows were put in individual pens and fed on poor quality hay *ad libitum* and had water.

Table 1: Feed proportions in the treatment rations (kg DM).

Ingredients	Treatments			
	TR ₁	TR ₂	TR ₃	TR ₄
Cotton seed cake (CSC)	315	480	-	-
Fish wastes (FW)	-	-	305	465
Hominy meal (HM)	665	-	675	-
Cassava root meal (CRM)	-	500	-	515
Minerals	20	20	20	20
Total	1000	1000	1000	1000

Before collection of data, the rumen environment was stabilized by feeding the animals 3 kg daily of a concentrate mixture composed of 0.3, 0.3, 0.2 and 0.2 parts CSC, FW, CRM and HM respectively and minerals at the rate of 2% of total ration. During the actual experiment, the cows were fed treatment rations at the rate of 11.6-g/kg body weight once every morning.

Data collection of rumen ecosystem. Samples for the rumen pH and $\text{NH}_3\text{-N}$ were collected before feeding at 07h and subsequently at interval of 2 hours for 24 hours. Prior to that all animals were acclimatized to the treatment rations for 10 days. Samples were collected every 11th day of the experiment for each treatment ration. Rumen liquor samples were obtained by squeezing ruminal contents collected 15 cm beneath the fistula opening. The fluid was then strained using surgical gauze into four 100-ml plastic jars; one for each cow and the rumen pH recorded immediately using a portable electronic pH meter. After the pH reading, three drops of concentrated sulphuric acid were added to the samples to avoid N losses. They were then ice parked in a cool box and immediately transported to the laboratory and stored at -200°C until they were analyzed for $\text{NH}_3\text{-N}$ after being centrifuged at 3000 rpm for 15 minutes. $\text{NH}_3\text{-N}$ content was determined using the Kjeltec distillation unit using a strong alkali (NaOH) instead of a weaker Magnesium oxide (MgO) (A.O.A.C., 1990; Kimambo *et al.*, 1999).

Rumen degradability study. Dry matter degradability (DMD) of the individual feeds and treatment rations were determined *in Sacco* (Ørskov *et al.*, 1980). Two-labeled nylon bags of size 40 to 50 mm containing 2 g of each sample were labeled and incubated in four animals at different time intervals of 6, 12, 24, 48, 72 and 96h for feed ingredients and up to 72 h for treatment rations. For each incubation time, the bags were removed from the rumen, washed in running tap water until the water was clear. The bags were then run through a stomacher (Model 400 Lab Blender)

to minimize microbial contamination and immediately stored in a deep freezer at a temperature of between -15°C and -20°C to stop further microbial activity. After thawing, all samples were filtered on labelled N-free filter papers and dried at 100°C for 24 hours and their residual weights calculated. Samples were then digested and distilled for the determination of nitrogen using the Kjeltec distillation unit (A.O.A.C., 1990).

The percentage of DM degraded (P) at time t, was determined according to the mathematical model $P = a + b (1 - e^{-ct})$ (McDonald, 1981). Where P is proportion of the DM degraded at time t, a is the zero time intercept (of degradation curve at time zero), b is the potentially rumen degradable portion, c (h^{-1}) is the rate constant at which b is degraded, a + b is the potential rumen degradability (asymptote). All the degradability characteristics and those at 48-hours were calculated from raw data using the NAWAY computer program developed by the Rowett Research Institute, Aberdeen, U.K (Shem *et al.*, 1995). The feed's metabolizable energy (ME) was calculated according to the following formulae:

$\text{ME (MJ/kg DM)} = 0.15 \text{ or } 0.16 \text{ DOMD \%}$
(MAFF, 1975)

Where $\text{DOMD} = 0.98 \text{ DMD \%} - 4.8$. Where $\text{DOMD \%} = \text{Dry organic matter digestible and DMD \% (g/kg DM)}$ = in this case was the 48h degradability. The coefficient was varied according to the class of feed; 0.15 was used for hay and 0.16 for supplementary rations also according to MAFF (1975).

Chemical analysis. The feed ingredients (CSC, FW, HM, CRM and hay), treatment rations and residual samples were analyzed for their chemical contents (DM, Ash and CF) using the proximate analysis (A.O.A.C, 1990). Crude protein (CP) was determined using a semi- automatic Kjeldatech method and ether extract (EE) was determined by using Soxhlet extraction technique. Neutral detergent fiber (NDF) and acid detergent fiber (ADF)

contents were also analyzed according to the method of Van Soest *et al.* (1991).

Statistical analysis. All the data collected were analyzed using the General Linear Model Procedure (GLMP) and means were compared using the LSD method (SAS, 1990).

Results

The chemical composition of the feed ingredients namely CSC, FW, CRM, HM and hay are presented in Table 2. FW collected in the dry season had higher ($P<0.05$) DM and EE than that during the rainy season but all had higher CP, EE, DM and Ash contents than CSC. In the same table, CRM had lower ($P<0.05$) CF, EE CP contents than hominy meal (HM) and hay had the lowest CP and highest NDF and ADF of all the feed ingredients.

Chemical compositions of the treatment rations are also summarized in Table 2. The average (DM) contents of the treatment rations were above 960g/kg DM and their CP was almost similar in all rations (201-206 g/kg DM). Crude fat (EE) was highest in TR₃ (94 g/

kg DM) and lowest in TR₂ (26 g/kg DM). Ash content was highest in TR₄ (240 g/kg DM) and lowest in TR₁ (69 g/kg DM). Energy content was highest in rations containing CSC (TR₁ and TR₂) and lowest in rations with FW (TR₃ and TR₄).

Rumen pH values were not ($P>0.05$) different between treatments (Table 3). However, NH₃-N levels were ($P<0.05$) different (TR₃ (283.7 mg/l), TR₄ (203.7 mg/l), TR₂ (183.9mg/l) and TR₁ (135.8 mg/l). There was a rapid surge in NH₃-N between 1 and 2 hr after feeding in all rations followed by a rapid decline after the 3rd hour (Figure 1). NH₃-N levels evened out but were higher for treatments containing FW.

The degradability characteristics and ME data for the feed ingredients and the feed rations are shown in Tables 4 and 5 respectively. Degradability characteristics were higher ($P<0.05$) in CSC than in FW except for *c* (h^{-1}) value (0.069 h^{-1}), which was higher in FW than in CSC (0.046 h^{-1}). Energy content (ME) was also higher ($P<0.05$) in CSC (10.8 MJ/kg DM) than in FW (5.5 MJ/kg DM). The degradation rate constant (*c*) was higher

Table 2: Chemical composition of experimental feeds and treatment rations (g/kg DM).

Feed type	DM	CP	EE	ASH	NDF	CF	ADF	Ca	P	K	Na	Mg	ME
Fish wastes													
Rainy season	961	396	151	347				98	40.0	4.8	5.4	2.0	
Dry seasons	985	397	218	344				136	71.5	4.5	6.4	2.11	
Cassava root													
Whole CRM	921	43	8	51				0.9	4.5	2.9	4.1	3.7	
Other experimental feeds													
Cotton seed	958	373	75	63	51		347						
Hominy meal	964	139	85	46	630		80						
Hay	967	42	5	89	794		554	5.2	1.3	12.3	3.2	1.5	
Treatment rations													
TR ₁	969	201	76	69	449	113		4.6	6.4	12.9	4.3	3.6	13
TR ₂	967	202	26	74	426	116		6.3	2.6	17.0	6.4	3.1	12
TR ₃	973	203	94	167	470	51		44.2	17.8	9.3	5.4	3.0	11
TR ₄	972	206	58	240	601	63		61.9	28.9	11.0	4.7	1.8	9

DM = Dry matter, CP = Crude protein, EE = Ether extract, CF = crude fiber, SD =sun dried NDF = Neutral detergent fiber, ADF = Acid detergent fiber, ASH = Ash, ME = Metabolizable energy.

Table 3: Rumen NH₃-N (mg/l) and pH from fistulated cows fed on treatment rations.

Parameter	Treatments				SEM	Pr > F	Significance
	TR ₁	TR ₂	TR ₃	TR ₄			
pH	6.4 ^a	6.2 ^a	6.1 ^a	6.3 ^a	0.099	0.0001	***
NH ₃ -N	135.8 ^d	183.9 ^c	283.7 ^a	203.7 ^b	24.81	0.0001	***

*** = Highly significant at P < 0.0001.

Super script ^{a, b, c, d, ...}; means within each row bearing same letter are not significantly different at P < 0.05.

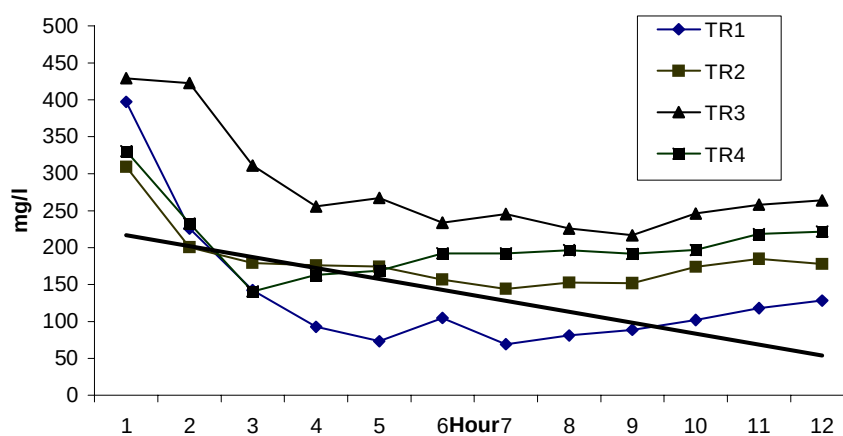


Figure 1: Diurnal change in rumen NH₃-N according to treatment.

Table 4: DM degradation characteristics a, b, (g/kg DM), c (h⁻¹) 48h and metabolizable energy (ME) (MJ/kg DM) of the experimental feeds.

Feed ingredient	a	b	a + b	48h	c	ME
FW	116 ^e	297 ^c	413 ^c	397 ^d	0.069 ^b	5.5 ^d
CSC	285 ^c	537 ^b	822 ^b	739 ^c	0.046 ^b	10.8 ^c
HM	356 ^b	622 ^a	978 ^a	835 ^b	0.031 ^b	12.3 ^b
CRM	603 ^a	322 ^c	925 ^a	920 ^a	0.153 ^a	13.7 ^a
Hay	152 ^d	234 ^d	386 ^c	362 ^d	0.058 ^b	4.9 ^d
SEM	0.770	1.815	1.619	1.435	0.024	0.328
Pr > F	0.0001	0.0001	0.0001	0.0001	0.0378	0.0001
Significance	***	***	***	***	*	***

ME = 0.16 * DOMD% and DOMD% = 0.98 DMD% - 4.8 and DMD% = 48h DM.

* = Significant at P < 0.05.

*** = Highly significant at P < 0.0001.

Super script ^{a, b, c, d, ...}; means within each column bearing same letter are not significantly different at P < 0.05.

Table 5: DM degradation characteristics (g/kg DM), and Metabolizable energy (ME) (MJ/kg DM) of the treatment rations.

Feed rations	a	b	a + b	48h	c h ⁻¹	ME	DMD %	OMD %
TR ₁	328 ^b	656 ^a	983 ^a	807 ^a	0.024 ^{cb}	11.9 ^a	684	736
TR ₂	237 ^c	566 ^b	803 ^c	791 ^{ba}	0.089 ^a	11.7 ^a	733	793
TR ₃	333 ^b	586 ^b	920 ^b	727 ^b	0.019 ^c	10.6 ^b	639	77
TR ₄	418 ^a	268 ^c	682 ^d	616 ^c	0.034 ^b	8.9 ^c	719	840
SEM	0.473	2.478	2.209	2.021	0.005	0.209		
Pr > F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		
Significance	***	***	***	***	***	***		

ME= 0.16*DOMD% and DOMD%= 0.98 DMD%-4.8 and DMD%= 48h DM.

*** = Highly significant at P <0.0001.

% = Invitro: 48h Dry matter digestibility (DMD) and Organic matter digestibility (OMD).

Super script ^{a, b, c, d}; means within each column bearing same letter are not significantly different at P<0.05.

(P<0.05) for TR₂ (0.089h⁻¹) and lowest in TR₃ (0.019 h⁻¹) and the insoluble but potentially degradable fraction (**b**), 48h DM degradability and potential degradability (**a+b**) were lowest for TR₄. The latter ration had the lowest (P<0.05) metabolizable energy (ME) (8.91 MJ/kg DM) and TR₂ the highest (11.65 MJ/kg DM). Protein source seem to have had influence on the ration's degradability characteristics and ME content as treatments containing FW (TR₃ and TR₄) had higher (P<0.05) degradability characteristic **a** compared to TR₁ and TR₂. Energy source also had influence on potential degradability (**a+b**). Treatment rations containing HM showed higher (P<0.05) potential degradability values than those containing CRM.

Discussion

The pH values obtained in this study were within recommended range for ruminants feeding on low quality roughage (Klasmeyer *et al.*, 1990; Kimambo *et al.*, 1999). Inclusion of CRM adds to the rapidly fermentable sugars, compounds that are known to lower rumen pH (Sommart *et al.*, 2000). However, the inclusion of CRM in TR₂ and TR₄ did not change the rumen pH values probably due to high production of volatile fatty acids (Sommart *et al.*, 2000). The latter authors reported that even at an inclusion rate of 54%

CRM failed to lower or affect rumen pH and function respectively. At around pH 6 rumen functions are not likely to be severely interfered (Klasmeyer *et al.*, 1990). Like in the latter author's study, rumen pH values did not deviate from neutrality.

The relatively high rumen NH₃-N values observed for CRM containing diets were in contrast with the findings by Pham King Cuong *et al.* (2001) who reported lower values from CRM fed cattle. This was probably due to the partial degradability of FW in the rumen and the high requirement of rumen NH₃-N for diets with high CP content (Odle and Schaefer, 1986). When CRM replaced HM as energy substrate in TR₂, the levels of rumen NH₃-N were significantly raised. This probably arose from the fact that there was an increased energy supply in the rumen activating the rumen microbes and thus the degradation of CSC at a faster rate.

Cotton seed cake had high DM degradation rates than FW; an indication of the former feed's higher degradability. Possible explanations for the difference in DM degradability of FW and CSC include, differences in solubility, chemical characteristics and presence of cross-linked disulphide bonds or cyclical structures of the protein (Preston and Leng, 1987; Pham Kim Cuong *et al.*, 2001). Khan *et al.* (1998), Kimambo *et al.* (1999), Pham Kim Cuong *et*

al. (2001) also reported lower DM and/or N disappearance in the rumen from protein sources of animal origin than those of vegetable origin except casein.

Therdchai and Mikled (2001) reported over 94 % of CRM to be degraded in the rumen, while Ørskov (1986) and Therdchai (1987) reported over 40% of corn carbohydrates to escape rumen degradation. Further more Smith *et al.* (1991) and Kanjanapruthipong *et al.* (2001) observed carbohydrates in cassava to be degraded twice or thrice faster than those of corn. Supriyati *et al.* (1995) and Barkrie *et al.* (1997) reported that multiplication of rumen microbes could be significantly increased following inclusion of CRM as an energy substrate. Through this method, Barkrie *et al.* (1997) were able to produce “Cassapro” (fermented cassava roots) via solid-state fermentation using CRM and *Aspergillus niger*. Cassapro is currently a popular ingredient in ruminants’ diets in Indonesia (Supriyati *et al.*, 1995; Barkrie *et al.*, 1997).

Treatments containing CSC were rich in ME and had higher DM degradability than those containing FW due to the good interaction between protein and energy at the rumen level. The main differences in DM degradation between treatment rations with FW compared to that of CSC was due to the by pass protein of FW in TR₃ and TR₄ (Barlow and Windsor, 1984).

Conclusion

The high DM degradability of the feed ingredients and treatment rations and their improvement on the rumen ecosystem results (pH and NH₃-N) suggest that supplementary feeding of CRM and FW to ruminants instead of CSC and HM is ideal under practical feeding conditions.

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Participatory evaluation and improvement of cassava and sweetpotato processing machines for the Eastern zone of Tanzania

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Abstract. Cassava and sweetpotatoes are important crops for improving livelihood of Tanzanians but have not been fully exploited, partly due to limited use of appropriate technologies to produce value added products. Most of the common cassava processing machines available in the market, but not popular in Tanzania, were chippers and graters of the International Institute of Tropical Agriculture (IITA) design. Popularization of such machines in Tanzania requires thorough participatory testing with stakeholders. Testing of the manual chipper and engine-powered grater in Muheza and Kibaha districts for peeled cassava resulted in unsatisfactory results. These were throughput of 11-18 kg/h and 270 kg/h for the manual chipper and the engine-powered grater, respectively. Despite the low throughput they were very difficult to operate. The engine-powered chipper resulted in throughput of 752 kg/h but lack of safety belt cover discredited it. Improvement on these machines mainly included use of pillow block bearings and increased stability for the manual chippers, provision of safety belt cover for the engine-powered chipper, and change of feed hopper design for the engine-powered chipper and grater. The exit chute design for the engine-powered grater was also modified. The modified machines were ergonomically satisfactory and their throughput increased by more than 100% with high acceptance levels. These machines are

capable of processing cassava and sweetpotatoes into various value added products. From the capital cost point of view farmers can easily acquire manual chippers. Engine-powered machines are relatively expensive and can be acquired by a group of farmers or a single entrepreneur.

Introduction

Cassava (*Manihot esculenta*) and sweetpotato (*Ipomoea batatas*) roots are very important for the livelihood of Tanzanians. Cassava is more productive per unit of land and labour than even the high yielding cereals (Moran, 1976) and the highest producer of carbohydrate of all cereals and tubers (Vries, 1978). It is also increasingly becoming important in the fresh, boiled, roasted and fried forms (Ndunguru *et al.*, 1994; Nweke, 1994). The remarkable importance of sweetpotato tubers is the easiness to convert its carbohydrate into starch at the household enterprise level (Marter and Timmins, 1992) and suitability for consumption during hard labour due to its high sugar content. With the roots/tubers being the main edible part, these crops are highly perishable once harvested. Cassava deteriorates 2-3 days after harvesting mainly because the roots are reproductively inactive (Emekoma, 1994), hence the rapid setting in of physiological changes and subsequent rot and decay (Booth, 1976; FAO, 1986). Losses of up to 50% in monetary value

have been reported (Ndunguru *et al.*, 1999). Inefficient harvesting and post-harvest handling (Boccas, 1987) can contribute to more quantitative losses.

Sweetpotato deteriorates at relatively lower rate with shelf life of almost 4 weeks (Anon, 1991). Sometimes, farmers use delayed harvesting tactics, with cassava being able to survive up to 2 years (Moran, 1976) and harvest the crops when required but this form of storage leads to poor quality and unnecessary holding of land. As the conventional storage methods are not feasible for these crops, the practical is processing into value added products. This enhances rural income generation (Wheatley *et al.*, 1996) and food security since simple and low cost technologies can be used. Introducing cassava processing in areas where the crop was only consumed in the fresh forms was successful in Latin America (Best *et al.*, 1991; Henry, 1992).

In Tanzania, traditional processing of cassava entails fermentation processes employed for the bitter varieties and non-fermentation processes employed for the sweet cassava varieties to obtain dry products for flour production. In these methods peeling, size reduction through multiple slicing by hand held knife, and sun drying are involved. In addition to processing into flour, sweet cassava varieties are grated for making local dishes using a rasped metal sheet (Silayo *et al.*, 2001). These methods are very rudimentary, leading to low appeal, short shelf lives, and in isolated areas high cyanogenic residues among others (Msabaha and Rweyangira, 1990). Improved and appropriate processing and packaging techniques will eliminate these problems (Nweke *et al.*, 1998).

Improved processing requires use of tools and techniques that are reliable, efficient, labour saving, safe, simple, and cost effective. The manual vertical reciprocating slicing machine developed at Sokoine University of Agriculture (Silayo *et al.*, 1999) was hard to operate and inefficient, requiring a lot of improvement. The noble way has been to adapt cassava chipping/slicing and grating

machines of the International Institute of Tropical Agriculture (IITA) design, previously not known in Tanzania. An approach to involve farmers right from the field trials of these machines was used. The main objective of this study was therefore to establish suitability of some IITA chipping and grating machines for adaptability in Tanzania based on farmers own perceptions and evaluations.

Materials and Methods

Acquisition and description

Manual slicers. A manually operated slicing machine (Figure 1) of the IITA design equipped with a two-blade slicing disc was obtained from Uganda. This was made to be fixed on a table but due to seemingly added costs of fixing it permanently on a table and thereby rendering it immovable, a decision was made to manufacture a similar one (Figure 2) locally with provision for fixing on four light wooden stands. This would allow personnel to work while standing and quick manoeuvre. For each of the machine, chipping disc for interchangeability of slicing and chipping activities was also manufactured. The manufacturing work was done in collaboration



Figure 1: Manually operated slicing machine.



Figure 2: Manually operated slicing machine with wooden legs.

with Reliable Motor Works workshop in Dar es Salaam. The main functioning features of the manual chippers/slicers were the frame, the chipping/slicing disc, and a small feed hopper with a feed chute that progressively increases from 4 to 10 cm and two-stage feeding angles, the first one at about 30° and the second one at about 60° from the horizontal plane to the chipping/slicing disc. The chipping/slicing disc was mounted vertically with disc shaft running through sleeve bearings. The chipping disc featured eight symmetrical clusters of 5 mm diameter holes, each cluster bearing 14 holes in double rows running in convex mode from the centre to the periphery. Disc support stiffeners separated clusters where the disc was firmly bolted.

Engine powered chipper (Figure 3). This was also acquired from Uganda and featured a feed hopper that was wide (45 cm x 30 cm) and slightly inclined (8°) to the horizontal, a chipping disc mounted on the frame with pillow block bearings, a system of pulleys, a driving belt, and a 5 HP petrol engine (Briggs and Stratton type). Configuration of the chipping disc was the same as for manual chipper described above. Power transmission

ratio was 1 to 4, and distance between pulley centres was about 50 cm.

Engine powered grater (Figure 4). This was also of the IITA design manufactured in collaboration with Reliable Motor works in Dar es Salaam. The main features were a two-side concave hopper with 30 cm x 30 cm feed opening, a horizontally mounted rasped drum



Figure 3: Engine powered chipper.

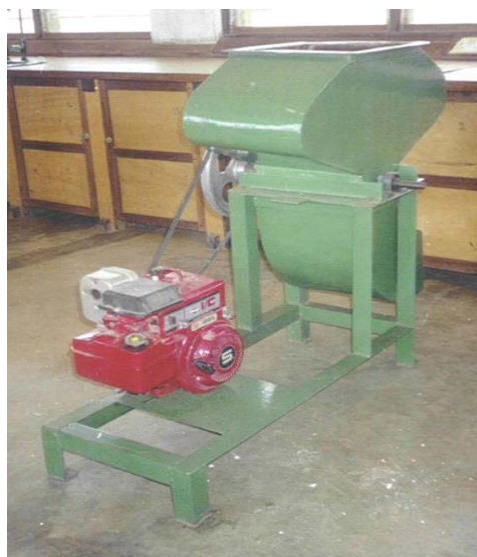


Figure 4: Engine powered grater.

at about 30 cm from the opening with the gripping surface 3 cm below the drum top surface, an exit chute oriented about 30° from the horizontal, a system of pulleys, and a driving belt for transferring power from a 5.5 hP petrol engine. The rasped surface resembled that of the traditional cassava-rasping sheet (Figure 5) used for small-scale grating (Silayo *et al.*, 2001). The drum length and diameter were about 29 cm and 18 cm, respectively. Power transmission ratio was 1 to 4 and distance between pulley centres was about 60 cm. The gap between the drum and the gripping surface was about 4 mm. Modification of chipping and grating machines

Chippers. Modifications to the equipment above (Figures 2, 3 and 4) were made based on recommendations from the participating farmers, extension agents, researchers, and local equipment manufacturers after testing the equipment. Following this, several modifications were made and participatory testing exercises conducted in order to improve performance and acceptability. Made in collaboration with Intermech Engineering Co. Ltd of Morogoro, the concluded modifications were use of pillow block bearings (Figures 6 and 7) for the manual chippers and fixing of the wooden stands in a trapezoidal mode for the manual chipper on wooden stands (Figure 7).

A more improved version of chipper called pedestal-type chipper was also manufactured (Figure 8). This took the same features of the

modified manual chippers but with increased hopper size (39 cm x 35 cm) and a welded metal stand, making the overall height of the machine 95 cm. Another modification was a re-design of the engine-powered chipper to make it dual purpose so that it could be operated with a 3.5-5.5 HP engine or without



Figure 6: Table mounted manual chipper with pillow block bearings.



Figure 7: Wooden legged manual chipper with pillow block bearings.



Figure 5: The traditional cassava-rasping sheet.



Figure 8: Pedestal-type chipper.



Figure 9: Engine-powered pedestal-type chipper.

the need to imitate the pedestal-type chipper and provision of belt safety cover (Figure 9).

The grater. Modifications to the grater mainly included provision of a hopper box (42 cm x 40 cm) with a base inclined at about 35° extended close to the top surface of the rotating drum in order to improve gripping to the working surface and minimize splattering, and a vertical straight rectangular (40 cm x 22 cm) exit chute (Figure 10). The drum was made

of hard wood, with length and diameter of 39 cm and 15 cm, respectively. The drum was fixed with stainless steel pins instead of rasped aluminium or galvanized sheet. The pins were fitted in about 12 rows along the length of the drum at intervals of about 2 mm from pin to pin and protruding 2 mm above the drum surface. The drum was run by a 5.5 HP engine (Briggs and Stratton type), with power transmission ratio of 1 to 2 and 30 cm distance between the transmission pulleys.

Equipment testing. Due to the high cost of making a working table for fixing cassava slicing/chipping machine, the manual chipper/slicer that was meant to be operated while fixed on a table was operated while held firmly on the ground (Figure 1), parallel with the same design that was improvised with wooden legs (Figure 2). At both the inception and the modification stages chipping and grating machines were tested by 40 participating farmers about half of them women, in collaboration with researchers and extension agents in Kibaha and Muheza districts and researchers at Sokoine University of Agriculture. The experiments were done on local cassava varieties and prior to chipping and grating the roots were peeled



Figure 10: Engine powered grater.

and washed to avoid introducing soil particles that could damage the moving parts of the machines. The parameters evaluated were weight processed and processing time. These were converted to throughput (kg/h). Other parameters included percent losses measured as the amount that passed through the machine without being processed, acceptability, and physical attributes of the machines during processing. The mean throughputs and losses were compared using analysis of variance and separated using Duncan's Multiple Range Test ($P=0.05$) (Steel and Torrie, 1980).

Results and Discussion

Performance of the newly introduced machines

Chippers/slicers. Operating the manual slicer/chipper with the two-blade slicing disc

was very difficult, and some farmers, especially women failed to crank the disc continuously. This led to rejection of these machines when fitted with the two-blade slicing disc by almost all farmers who participated in the testing. With the slicing disc replaced with the chipping disc the machines (chippers) performed slightly better but the throughput values were still very low (Table 1). Working with the manual chipper fitted with wooden legs resulted in higher output compared with working with the same machine on the ground while bending. However, use of these machines was labour intensive, as they require two operators, one for feeding and another for cranking the chipping disc. Manual chipping resulted in high losses (19-20%). These were the portions that were just broken and some passing without being processed. This was caused by high concentration of fibers at the end of the roots, which resulted in the last bits of

Table 1: Performance and acceptability of chipping and grating machines before modifications.

Type of machine	Factory price (T shs)	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	40,000	11.4±1.3 ^d	20±2.01 ^b	26.9
Manual chipper fixed on wooden stands	45,000	18±1.9 ^c	19±1.80 ^b	26.7
Engine-powered chipper	-	752±2.0 ^a	7±1.20 ^c	58.4
Engine-powered grater	790,000	270±6.32 ^b	29±2.49 ^a	2.5

Values bearing different superscripts in a column are significantly different ($P<0.05$).

Table 2: Performance and acceptability of chipping and grating machines after modification.

Type of machine	Factory price (T shs)	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	60,000	81.6±0.19 ^e	18.03±1.11 ^c	49
Manual chipper fixed on wooden stands	70,000	99.3±0.30 ^d	17.2±0.93 ^c	54
Pedestal type chipper	120,000	136±0.14 ^c	14.8±1.30 ^a	93
Engine-powered chipper	780,000(5.5 HP engine)	768±1.78 ^a	5.68±0.51 ^b	89
Engine-powered grater	780,000(5.5 HP engine)	507.7±2.52 ^b	Nil	74

Values bearing different superscripts in a column are significantly different ($P<0.05$).

cassava not being processed, suggesting the removal of the end portions before chipping. The thin roots also ended up being broken or passed without being processed. In addition, manual chippers were still difficult to operate as observed by 50% and 29 % of the respondents for the chipper operated while on the ground and that fixed on wooden stands, respectively. This was mainly due to the use of sleeve bearings on the disc shaft. The former was more difficult to operate because one had to bend while operating it, making it more ergonomically unfit. The engine-powered chipper had the highest score, including throughput, which was more than thirty times the manual chippers. Nevertheless, this machine showed some drawbacks, including allowing passage of unprocessed chunks. This was due to the same reasons as for the manual chippers. Another drawback was exposure of the driving belt, which was a safety hazard. Acceptability of the manual chippers was low, (27%) while that of the engine-powered one was relatively high (58.4%). The results show an increase of acceptability with increasing throughput and decreasing losses (Table 1), implying that these factors influence adoption rates. Some respondents (25%), however, suggested the need to experience working with all the types of chipping machines, with an implication that the observed performance could have been higher.

The engine-powered grater. In comparison with the local rasping sheet that can only produce about 4 kg/h of grates (Silayo *et al.*, 2001) the performance shown by the engine-powered grater (270 kg/h) was relatively high (Table 1). However, the machine faced almost absolute rejection by farmers, advocating improvement. This was due to a number of problems including choking of the exit chute due to low angle of exit, low gripping by the drum due to poor hopper design, and splattering of cassava chunks due to poor hopper design and high speed of the drum, which were caused by design and

manufacturing errors. To assist gripping, one had to press cassava against the drum using a wooden paddle fixed on a long stick, which was cumbersome.

Performance after modifications

Chippers/slicers. Mean throughput of the improved manual chippers (Table 2) increased by more than five times while that of the improved engine-powered grater increased by about two times compared with the unimproved ones (Table 1). The increase in throughput corresponded to decrease in losses and increased acceptability despite the relatively higher purchasing cost. Improved throughput was due to provision of pillow-block bearings on the disc shaft of the manual chippers that resulted in smooth rotation compared with use of sleeves before modification. Same as before modifications the manual chipper on wooden stands demonstrated higher performance (99.3 kg/h) than when operated on the ground (81.6 kg/h). The pedestal-type chipper (Figure 8) resulted in throughput that was 16% higher and losses that were 13% lower than for the modified manual chipper on wooden stands. This was mainly due to the use of pillow-block bearing and increased feed hopper size, although stability due to increased weight by the supporting metallic structure could also have contributed. This suggests that throughput from the manual chipper on wooden stands could be improved further if the hopper size was increased. Use of the engine-powered chipper resulted in about eight times and six times as much throughput compared with the modified manual chipper on wooden stands and the pedestal-type chipper, respectively. The respective losses were lower by about 67% and 62%, showing superior performance of the engine-powered chipper. The results also indicate a positive correlation between increase in acceptability with increasing throughput and decreasing losses, making the pedestal-type chipper the best preferred amongst the manual chippers,

irrespective of the relatively high cost. At the purchasing cost of about 780,000 Tanzanian shillings, the engine-powered chipper resulted in a very high throughput but its acceptability decreased slightly from that of the pedestal-type chipper. This was due to higher cost compared with pedestal-type chipper. This implies that acceptability of chipping machines is a compromise between performance and capital cost. Consequently, this requires careful consideration by technology developers, manufacturers, and extension agents for adoption and sustainability. Preliminary testing of chipping machines with sweetpotatoes also produced good chips. These chips could be used for frying or drying where there is need.

The modified engine-powered grater.

Throughput of the modified grater (Table 2) was almost twice as much that of the unmodified one (Table 1) and no losses were experienced. Due to the absence of other versions of graters to compare with apart from the crude rasped sheet acceptability of the improved grater was high. The observed throughput would increase if operators experienced working with this machine for a longer time. The paste produced was generally fine except a few large fibrous particles that could be removed manually before further use for products such as starch and *kibabu* (*kebab*) (Silayo *et al.*, 2003).

Conclusions

The participating stakeholders successfully tested the manual chipping machine and the engine-powered chipper received from Uganda. Performance of the manual chipper was unsatisfactory while that of the engine-powered chipper was satisfactory pending provision of safety belt cover. Performance of the IITA design of grater made in Tanzania was also unsatisfactory. Due to involvement of farmers in the testing successful

modifications of these machines were achieved and performance improved. However, the manual chippers need to be made with enlarged feed hopper to increase throughput. Due to its superiority over other chippers, the pedestal-type chipper needs popularization for wider use to produce chips. The slicing disc for interchanging with the chipping disc need to be improved and the performance of the subsequent processes on chips and slices be evaluated and compared. Intensive work on use of these machines for diversifying use of sweetpotatoes is also required. Due to economic constraints it is recommended that the engine-powered machines (chipper and grater) be owned by farmers' groups or by a single entrepreneur for providing service to the community. Fuel consumption and energy expenditure on these machines under field conditions need to be evaluated. Innovations to produce improved manually operated graters for individual smallholder farmers seem inevitable. In order to attract more customers to acquire the proven modified machines a thorough cost-benefit analysis is required in all transects of societies involved in cassava and sweetpotato farming in Tanzania.

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The authors wish to acknowledge contribution by FOODNET for supplying the initial prototypes of the IITA manual chipper and the engine-powered chipper. Greatly acknowledged is TARP-II-SUA project funded by the Royal Government of Norway and the United Republic of Tanzania for supporting the research work that enabled involvement of researchers, farmers, extension agents, and equipment manufacturers, particularly the Reliable Motor Works of Dar es Salaam and Intermech Engineering of Morogoro. The later is highly commended for successful modification of these machines for adoption in Tanzania.

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Communique on Key Emerging Issues

1. Management of cassava brown streak disease (CBSD) in sub-Saharan Africa

Facilitator: Dr. James Legg

Summary of deliberations

1. Since the end of the AMANI cassava breeding programme in the 1960s, CBSD has been a neglected disease.
2. There were no published records of CBSD in Malawi until surveys were conducted by NRI in 1998 when the disease was found to be widespread with high incidences (70 – 100%) in some areas.
3. Work conducted by NRI in Tanzania and Mozambique between 1996 and 2003, have highlighted the threat to food security imposed by CBSD. As a consequence CBSD has now become a priority for research within IITA. A number of donor organisations have agreed to support adaptive research for the control of the disease.
4. Despite the increased international effort to combat CBSD, there are many fundamental aspects of the basic biology of the disease that are not well understood. While strategic and adaptive research on CBSD is receiving increased funding, this basic research remains neglected.
5. Gaps in our understanding of some fundamental aspects of the aetiology and epidemiology of CBSD are an obstacle to speedy progress with disease control.

Recommendations

The meeting recommends that donors should support basic research on CBSD to provide the knowledge required to assist efforts to control CBSD through plant breeding. Four important aspects require attention:

1. Taxonomy of the virus: Presently the closest affinity is with the potyviruses with a non-definitive 40% sequence similarity. The possibility that more than one particle type is required for symptom expression has been raised.
2. Vector transmission: whitefly is the obvious candidate but transmission tests with both species have not been successful.
3. Factors influencing infection and symptom expression: what is the effect of soil type and climate – why is the disease confined to lowland areas of eastern Africa?
4. Relationship between above ground symptoms and root symptoms and distribution of the virus within the plant – does reversion occur?

2. Promotion of orange-fleshed sweetpotato to combat vitamin a deficiency in sub-Saharan Africa: VITAA (Vitamin A for Africa) Partnership Programme experiences

Facilitator: Dr. Fina Opio

Summary of deliberations

In sub-Saharan Africa, researchers from eight countries (Tanzania, Mozambique, Uganda, Kenya, Ethiopia, South Africa, Zambia and Ghana) in collaboration with the Root Crops Research Networks such as PRAPACE in East and Central Africa as well as SARRNET in the Southern Africa are working together under the banner of the VITAA to resolve the health problems of millions of children under age five who suffer from Vitamin A deficiency. The objective is to integrate in the diets to the greatest extent possible, the new high beta-carotene rich varieties that the body can use to produce Vitamin A. Lack of this essential micronutrient usually leads to a breakdown of the immune system and eventual death or blindness.

VITAA, winner of the 2003 CGIAR outstanding partnership award, met as part of the 13 Triennial Meeting of the International Symposium of Tropical Root Crops. VITAA represents an important opportunity for the countries of southern and eastern Africa to tackle one of their most pressing public health problems using existing technology that has proven to be both effective and sustainable. With modest resources, VITAA is putting into the hands of local communities orange-fleshed sweetpotato varieties. VITAA analyses from six countries has pointed to the high potential impact of replacing white fleshed sweetpotato varieties with high-dry-matter orange-fleshed ones. Scientists estimate that some 50 million children under the age of six stand to benefit.

VITAA's governance is provided by a Steering Committee made up of nutritionists, public health experts and agriculturalists from national and international research and development programs and NGOs throughout the region. Because VITAA recognises the importance of women in sweetpotato production systems, the Committee also includes an expert in the field of gender analysis. The Steering Committee meets annually and provides oversight and guidance to the VITAA Coordinator, Dr. Regina Kapinga, an International Potato Center (CIP) scientist. A session at the 13th ISTRC was devoted to OFSP which highlighted that VITAA has been particularly successful in:

- Bringing together different sectors to address a common problem.
- Increasing awareness of the potential of food-based approaches in combating vitamin A deficiency (VAD).
- Highlighting the acceptability of OFSP to a wide range of cultural groups

Discussions at the session put across a need to:

- Encourage farmers to produce OFSP in tandem with further developing the market.
- Build on successful efforts on producing planting material to make it more widely available.

- Widen the genetic base to build on progress already made, specifically, to incorporate weevil and virus resistance and improve on dry-matter content.
- Undertake additional bio-efficacy studies with other at-risk groups to build on those successfully conducted with primary school children.

The meeting explored opportunities to link to similar initiatives in Asia and highlighted the potential of OFSP in disaster mitigation.

For further on information on the VITAA initiative please contact: Dr. R. Kapinga, VITAA Coordinator, Email: r.kapinga@cgiar.org, or visit the website: www.cipotato.org/vtaa

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Arusha, 10 - 14 November 2003

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Heap fermentation of cassava (*Manihot Esculenta* Crantz) in Nampula province, Mozambique

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Abstract. Cassava (*Manihot esculenta* Crantz), a tropical root crop, is an essential part of the diet of the inhabitants of Nampula Province in Northern Mozambique. The root is mostly consumed after processing by heap fermentation and sun-drying. The study investigated the microbial and biochemical changes occurring during traditional heap fermentations in three households. The cassava was fermented over a period of 4 days. Temperature values at which extensive mould growth was observed ranged from 26 to 29°C. Lactic acid bacteria increased from 10⁴ to 10⁶ cfu/g during the fermentation. Isolates were identified as *Leuconostoc pseudomesenteroides*, *Leuconostoc mesenteroides*, *Enterococcus faecium* and *Weissella cibaria*. Moulds identified were *Neurospora sitophila* and *Rhizopus stolonifer*. The pH values of the cassavas decreased from 6.1 ± 0.01 to 5.6 ± 0.6 during heap fermentation. Average total cyanogenic levels in non-fermented cassava flour was 158 mg HCN/kg, while in fermented cassava flour, a value of 17 g HCN/kg was recorded. Protein concentration in the cassava flour slightly increased from 1.3 % to 1.8 % w/w dry matter during fermentation.

Introduction

Cassava (*Manihot esculenta* Crantz) is a very important crop in Mozambique, where it is the second most important staple food after maize and contributes 42 % of the total food energy

(CIAT, 1990; Dahniya, 1994). Cassava is an essential part of the diet in Nampula Province, Mozambique and is mostly consumed after processing. The processing of the roots is mainly by sun drying (Zvauya *et al.*, 2002). Cassava flour is the mostly widely consumed cassava product in Nampula Province. The flour is made from chips that may be heap-fermented before sun drying or sun dried directly before milling into flour. Bitter varieties of cassava are normally fermented before sun drying and milling. The cassava flour obtained from fermented chips has a lower cyanogenic content than that obtained from non-fermented chips (Zvauya *et al.*, 2002). Non-fermented cassava has a low protein content, which remains relatively low in the fermented cassava chips (Essers *et al.*, 1995).

Very few studies have been carried out on the biochemical and microbial changes occurring during heap fermentation of cassava (Essers *et al.*, 1995). The fermentation is largely uncontrolled and results in variable quality products. A variety of microorganisms, including bacteria, yeasts and moulds are involved in the process, moulds being the most important (Essers *et al.*, 1995). The traditional heap fermentation process in Mozambique has not been studied previously. In this study, the biochemical and microbial changes occurring during heap fermentation of cassava were studied in Nampula Province, Mozambique. The predominant microorganisms were isolated and identified.

Materials and Methods

Study area. The fieldwork was carried out in Nacaroa District, Nampula Province, Mozambique. Nacaroa is located about 160 km North East from Nampula city, in the North of Mozambique, about 2000 km from the capital city, Maputo. The district is 3593 km² with about 86 000 inhabitants.

Traditional heap fermentation. The fermentation process was observed in three households located 3.4 km, 4.3 km and 7.1 km from Nacaroa Town. The fermentation processes were monitored for a period of 5 days from the onset until the end of fermentation where pH values were measured daily. Temperature was measured inside and outside the heap twice a day (morning and afternoon) throughout the fermentation. Samples were collected daily from the heaps for sun drying during 7 days at approximately 30 to 34° C. Afterwhich, cyanogens and crude proteins amounts were determined.

Enumeration of microbes. Samples (1 g) collected from the onset of fermentation until the end were placed into 9 ml peptone water (Oxoid, CM0009) and serial dilutions were made to 10⁻² and 10⁻³. Total aerobic mesophilic bacteria were determined on plate count agar (Oxoid, CM0325), lactic acid bacteria were determined using De Man-Rogosa-Sharpe (MRS) agar (Oxoid, CM0361) and yeasts and moulds were enumerated on Wort agar (Oxoid, CM0247). Cultures were incubated in air for 3 days at ambient temperature (30-32 °C).

Isolation of microbes. Further samples for microbial isolation and identification were collected from 3 localities: locality 1, situated 20 km West of Nacaroa Village; locality 2 in Nacaroa Village; locality 3 situated 20 km east of Nacaroa Village. Three family homesteads were visited in each locality. Samples of heap-fermented cassava roots at 1, 2 and 3 days of fermentation were collected from each family. In addition, dried cassava roots were collected.

Small pieces (1g) of fermented cassava collected from the heaps at different stages of fermentation were added to test tubes with 9 ml peptone water (Oxoid, CM0009). The contents of the test tubes were mixed by shaking and 0.1 ml of each suspension were then streaked over Wort agar (Oxoid, CM0247), Malt Extract agar (Oxoid, CM0059) and MRS agar (Oxoid, CM0361) plates. Cultures were incubated in air for three days at about 30° C. Predominant microbes were isolated and purified by repeated streaking of single colonies on the same media. The isolated microbes were preserved in 30% glycerol and stored at -80⁰C.

Identification of microorganisms. Bacteria were regenerated on APT agar (DIFCO 0654-17-0) by plating 0.1 ml of sample and incubating for 2 days at 30 °C. Cultures were observed under the microscope (1000x, Olympus, BH2). The bacteria were inoculated to APT broth (DIFCO 0655-17-9) and incubated at 30 °C. The final pH was measured after 48 h incubation at 30°C. The catalase test was done by emulsifying a loopful of growth from a plate with a drop of hydrogen peroxide (3%) on a slide and observing effervescence (Harrigan and McCance, 1966). For final bacterial isolates identification, RNA gene sequencing was used. Moulds were regenerated on Potato dextrose agar (Oxoid, CM0139) plates and their growth characteristics and reproductive structures were observed under the microscope (Olympus, BH2). A classification key was used for identification (Pitt & Hocking, 1997). Yeasts were also regenerated on potato dextrose agar (Oxoid, CM0139) but no attempt was made to identify the genera.

Determination of total cyanogen. Dry cassava pieces (5g) were placed into 10 ml of phosphoric acid (0.1 M) and stored at 4 °C until required. To extract cyanogens, the sample was homogenized and more 15 ml of 0.1M phosphoric acid added and later centrifuged for 10 min at 2500 rev min⁻¹.

Extracts were kept at 4°C until analysis. Total cyanogen in cassava samples was determined as described by Essers (1993). The enzyme, linamarase, used in total cyanogens assay was prepared from cassava latex as described by Haque and Bradbury (1999).

Determination of pH. Fermented cassava pieces (5 g) were suspended in 20 ml distilled water for pH measurement.

Total crude protein. Crude protein was determined by the revised kjeldahl method (NRI, 1996) for assessing quality characteristics on non-grain starch staples.

Results

Visual changes, temperature and pH in the heaps with time. No moulds were observed on the surfaces of cassava roots on the first and second days of fermentation but the surfaces of the roots became slimy, probably due to bacterial and/or yeast growth. Moulds appeared on the roots on the third day, starting with areas of root damage. On the fourth day, the moulds had almost covered all the roots and the roots were soft when touched and pressed. At this stage the cassava roots were ready to be dried in the sun.

Condensation was observed on the roots and the leaves during fermentation. At the beginning of fermentation, the inside and outside temperatures of the heaps were the same in the morning. However, by midday, the inside temperature was lower than the outside temperatures (Figs. 1 and 2). The pH of the cassava roots slightly decreased during fermentation (Table 1), probably due to lactic acid production by lactic acid bacteria.

Microbial analysis. It was difficult to determine reliable counts of total mesophilic bacteria, yeast and moulds due to extensive mould growth on the plates. Total lactic acid bacteria increased from 10^4 to 10^6 cfu/g during the fermentation (Table 1).

Identification of microorganisms. For lactic acid bacteria determination, a total of 10 bacterial cultures were selected, three were cocci and seven were rods. Three were catalase positive and seven were catalase negative. The catalase negative strains were taken for identification. Five were identified as lactic acid bacteria: *Leuconostoc pseudomesenteroides* (CNB4), *Leuconostoc mesenteroides* (CNB6), *Enterococcus faecium* (CNB7) and *Weissella cibaria*

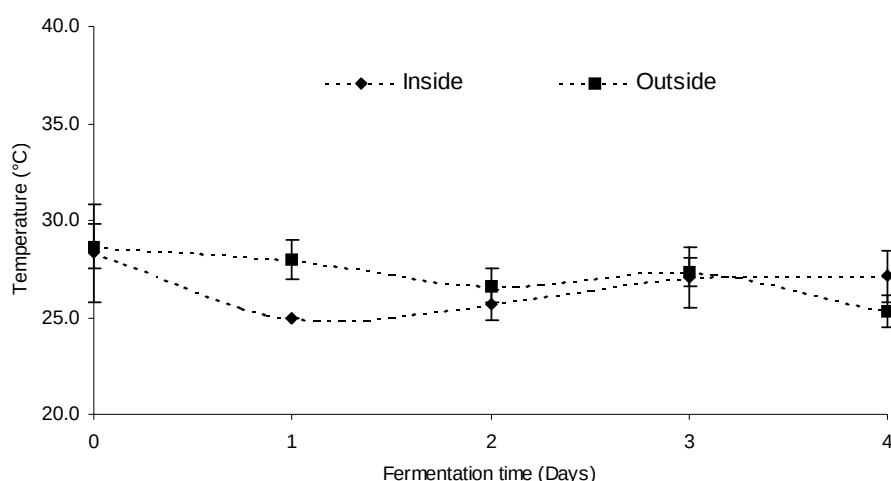


Figure 1: Temperatures inside and outside the heaps during traditional fermentation, measured in the morning (6.00 to 8.00 AM), n=3.

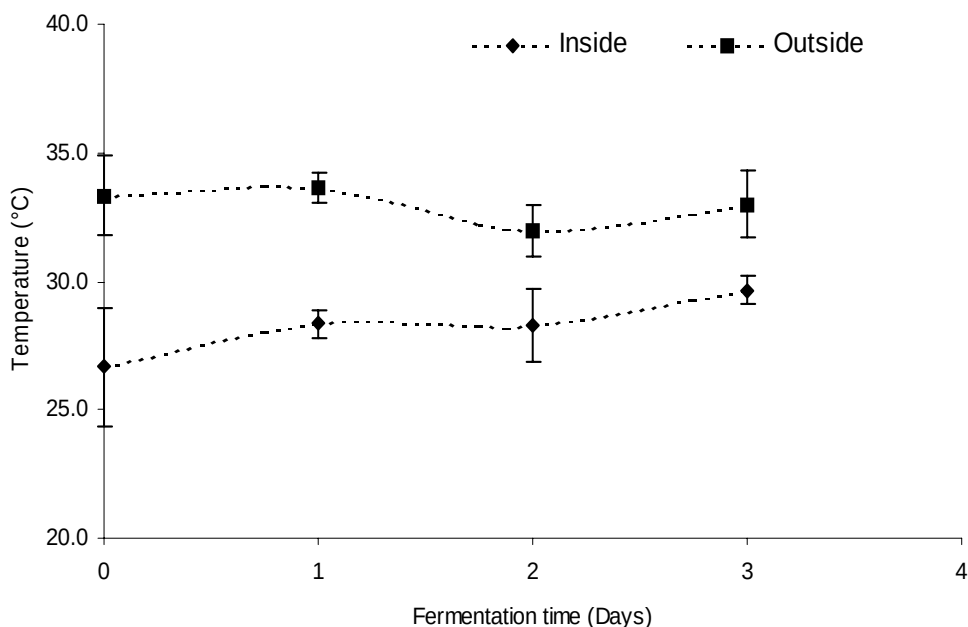


Figure 2: Temperatures inside and outside the heaps during traditional fermentation, measured in the afternoon (1.00 to 3.00 PM), n=3.

(CNB9) from cassava fermented. *Leuconostoc mesenteroides* (CNB10) was also isolated from dried cassava flour.

Moulds were observed in 2 to 3 day fermented cassava and in dry cassava. A black mould was dominant and grew in all the media used. Orange moulds were less evident on the fermented roots but grew well on media. The orange moulds were identified as *Neurospora sitophila* (CNF1) and the black moulds as *Rhizopus stolonifer* (CNF6).

Cyanogens content of dry cassava chips. The cyanogens content in dried fermented cassava chips was 9 - 14% of that in dried unfermented chips (Table 1).

Protein content of dried cassava chips. The average protein content in dried cassava roots slightly increased from 1.3 % to 1.8 % (w/w) dry weight after 3 days of fermentation (Table 1).

Discussion

High ambient temperature makes local peasants use a place where there is usually shade during the day to create a lower temperature for fungal growth. The heap environment is also improved by covering the roots to avoid moisture loss. In Nampula, heap fermentation takes place during the dry season. The temperature inside the heaps was lower than the temperature outside during the fermentation. Evaporation of the moisture lowered the temperature inside the heap. Essers *et al* (1995) found that the temperature of the incubated roots was 2 to 12 °C high than the ambient temperature near the heaps, which was between 23 and 29 °C in the mornings.

The slight decrease of pH was probably caused by production of lactic acid by bacteria. The pH was maintained between 6 and 5, which is ideal for the glycoside break

Table 1: Resume of pH, Lactic acid count in fermented cassava roots and total cyanogens ant crude protein in dried fermented cassava chips after different periods of fermentation.

	Fermentation time (days)				
	0	1	2	3	4
pH fermented cassava root (n=3)	6.12 ± 0.01	6.11 ± 0.07	5.97 ± 0.37	5.59 ± 0.48	5.65 ± 0.64
Total Lactic acid bacteria in fermented cassava root (Log cfu/g) (n=3)	3.3 ± 0.9	4.2 ± 0.2	5.2 ± 0.5	5.7 ± 0.1	5.8 ± 0.1
Crude protein concentration in dried fermented cassava root (w/w) (n=3)	1.33 ± 0.12	1.42 ± 0.06	1.49 ± 0.28	1.80 ± 0.16	1.61 ± 0.08
Total cyanogens in dried fermented cassava root (mg HCN/Kg) (n=3)	158.27 ± 20.44	117.39 ± 24.75	29.83 ± 12.73	23.23 ± 10.61	16.86 ± 6.35

down (White *et al.*, 1994). The moulds, *Rhizopus stolonifer* and *Neurospora sitophila* isolated here were also isolated and identified by Essers (1995). Moulds are the main microorganisms involved in heap fermentations. The fermentation plays an important role in reducing the residual total cyanogens in dried cassava chips. However, the cyanogens concentration in all the cassava samples (fermented and unfermented) were above the concentration (10mg/Kg) recommended by the Code Alimentarius Committee of the FAO/WHO (1991) as safe. Similar result were obtained in Uganda by Essers *et al.* (1995).

Conclusion

From the results obtained so far, it can be concluded that moulds are the dominant microbes involved in heap fermentation of cassava in Nampula Province, Mozambique. The fermentation reduces cyanogenic levels more than does sun-drying alone. The protein content of cassava roots slightly increased with fermentation.

Acknowledgments

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Application of consumer preference and sensory evaluation to sweetpotato research in East Africa

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Abstract. Sweetpotato is a major staple food and income source in several regions of Tanzania and other countries of sub-Saharan Africa. Research, funded by DFID Crop Post Harvest Programme, has sought to expand the potential for introducing improved cultivars, extend the storability of sweetpotato at the farm and prolong the shelf-life during marketing. Consumer preference and sensory evaluation can play an important role in these research projects and has been applied at the rural village level. This paper explores the sensory and consumer approaches developed and applied and outlines some of the statistical tools used to analyse and interpret the results. For example, in cultivar selection, sensory panels and consumer preference studies have been used to investigate regional and seasonal variations in the preference and sensory characteristics of sweetpotato cultivars. Models were developed to relate sensory attributes used by a trained panel to consumer preference. In other studies, simple techniques were developed for use by farmers so that sweetpotato could be evaluated under field conditions. Implications and approaches for future research are discussed.

Introduction

Sweetpotato is an important food crop in much of sub-Saharan Africa where annual production is estimated to be 9.9 million tonnes. The crop is often considered to be a

‘poor person’s food’ which can lead to the sensory and preference criteria of sweetpotato to be under represented and neglected. This paper discusses consumer preference and sensory evaluation approaches developed and applied in East Africa within collaborative projects involving Natural Resources Institute, University of Greenwich at Medway, UK and the Lake Zone Agricultural Research and Development Institute, Tanzania with inputs from the Kenyan Agricultural Research Institute, Kenya.

Discussion

This discussion indicates how consumer acceptability and sensory evaluation has been applied to sweetpotato in East Africa. Consumer testing has involved the evaluation of suitable methods for rapidly assessing preference in rural and urban locations. Detailed understanding of the sweetpotato cultivars was provided by a sensory panel that enabled models to be developed that can be used by those selecting local sweetpotato cultivars for quality (Rwiza *et al.*, 2000; Tomlins *et al.*, 2003ab). Sensory evaluation has also been applied to understanding sensory changes during shelf-life studies (Anon 2002; Oirschot *et al.*, 2003). Simpler sensory evaluation approaches have been used by rural farmers in Tanzania to compare simple methods for storing fresh sweetpotato

roots under tropical conditions (Anon 2002; Tomlins *et al* 2003c).

Case Study 1. Linking trained sensory panels to consumer preference to simplify cultivar selection.

Little has been reported on the use of trained sensory panels in the selection of sweetpotato cultivars in East Africa. Consumer testing requires interviewing at least 100 consumers which makes it time consuming and expensive. In East Africa, consumers in rural locations may be remote and vary in literacy and education. Simplified methods for rapidly measuring consumer acceptability in both rural and urban locations in Tanzania have been assessed (Rwiza *et al.*, 2000; Tomlins *et al.*, 2003ab). One investigated by NRI was the ranking method (ISO reference) and a simpler approach based on asking the consumer to say which of the sweetpotato cultivars they prefer the most.

Use of ranking methods in consumer preference and linking preference with socio-economic profiles of consumers. Rankings (ISO 1988) can be used to assess the consumer acceptability of several samples at the same time. In 1998, a total of 300 consumers equally divided between three locations Mwanza, Meatu, and Misungwi in the Lake Zone, Tanzania ranked the acceptability of locally available sweet potato cultivars. The cultivars

were locally grown and those available in the markets at the time of sampling. This meant that the varieties available differed from year to year although certain 'core' varieties (Polista, Sinia B and SPN/O) were consistently available. The Friedman's test indicated that the acceptability of the cultivars significantly differed at each location (Table 1).

At the three locations where a total of 300 consumers were interviewed, the cultivars with consistently high ranks for acceptability were Polista and SPN/O. Ngosha, Toniki and Ngikuru were also highly ranked but were only assessed once because they were local to these locations. The cultivar Sinia B was highly ranked by consumers at Mwanza but locally available versions at Meatu and Misungwi were ranked low as were Serena, Ipembe and Nguruka. The ranks for each consumer can be compared with socio-economic data collected at interview. The Kruskal-Wallis test showed that at Meatu female consumers significant ranked SPN/O ($P=0.044$) and Ipembe ($P=0.044$) cultivars as more preferred while men ranked these as least preferred. At Misungwi Sinia B ($P=0.013$) was significantly more preferred by women. Consumers who ate sweetpotato least often most preferred SPN/O at Meatu ($P=0.023$) and Misungwi ($P=0.057$).

Rapid and simple method for measuring consumer preference. A simpler and more

Table 1: Rank sums of preference of sweet potato cultivars by consumers at Mwanza.

Rank order	Mwanza (100 consumers)	Meatu (100 consumers)	Misungwi (100 consumers)
1	Polista (350)a	SPN/O (500) ^a	Ngikuru (457)a
2	Sinia B (337)a	Ngosha (420) ^b	SPN/O (388)b
3	SPN/O (315)a	Polista (410) ^b	Polista (351)b
4	Mzondwa (256)b	Serena (299) ^c	Toniki (350)b
5	Bilagala (242)b	Sinia B (255) ^c	Sinia B (283)c
6		Ipembe (187) ^d	Nguruka (249)c
F value	37.6	221.4	79.4
LSD ($P=0.05$)	43.8	51.3	51.6

Where: number in brackets is the rank sum, a, b or c donates grouping with respect to the least significant difference using the Friedman's test.

rapid method than ranking was evaluated (Tomlins *et al.*, 2003a). Using the data from the consumer in 1998, the rank sum for a cultivar and the percent of consumers who gave it the highest rank (assumed to indicate it was the consumer's most preferred cultivar) were compared. The relationship is illustrated in figure 1 using cultivars tested at Meatu. The correlation coefficients of 0.872, 0.954 and 0.953 obtained for comparisons at Mwanza, Meatu and Misungwi respectively indicated that the simpler method was comparable to the ranking method and suitable for use with consumers in Tanzania. The first choice preference approach to consumer testing was used to evaluate sweetpotato cultivars tested in 1998 and 2000 seasons at Mwanza, Meatu and Misungwi. The cultivars were locally grown and those available in the markets at the time of sampling. This meant that the varieties available differed from year to year although certain 'core' varieties (Polista, Sinia B and SPN/0) were consistently available. The percentages of consumers for whom each cultivar was the first preference are given in Table 2. While not all cultivar were available locally at each location, the two cultivars that were consistently the first choice were Polista and SPN/O.

Linking consumer preference and sensory evaluation in developing models for cultivar selection. A sensory panel scored the sweetpotato cultivars assessed by consumers in 1998 and 2000 in Mwanza, Meatu and Misungwi. This enabled the comparison of locational and seasonal effects in addition to giving a more detailed sensory assessment of the samples.

A sensory panel using Quantitative Descriptive Analysis (Meilgaard *et al.*, 1987; Bainbridge *et al.*, 1996, Tomlins 1998) used 11 sensory attributes to describe the appearance, taste and texture. Cluster analysis (Hierarchical Cluster Analysis, Wards Method, Euclidean distance) of the sensory attributes for the combined years identified three groups of cultivars according to similarity of sensory properties (Figure 2). Cluster 1 was comprised mainly of cultivars that were named as the most preferred by a relatively small percentage of consumers (on average only 19% preferred these the most). The cultivars within this cluster were predominantly Mzondwa (98 and 00), Serena (98 and 00) and Sinia (98). Cluster 2 was comprised entirely of the cultivars from Misungwi (00) and suggests a locational effect for that year (on average 36% preferred these

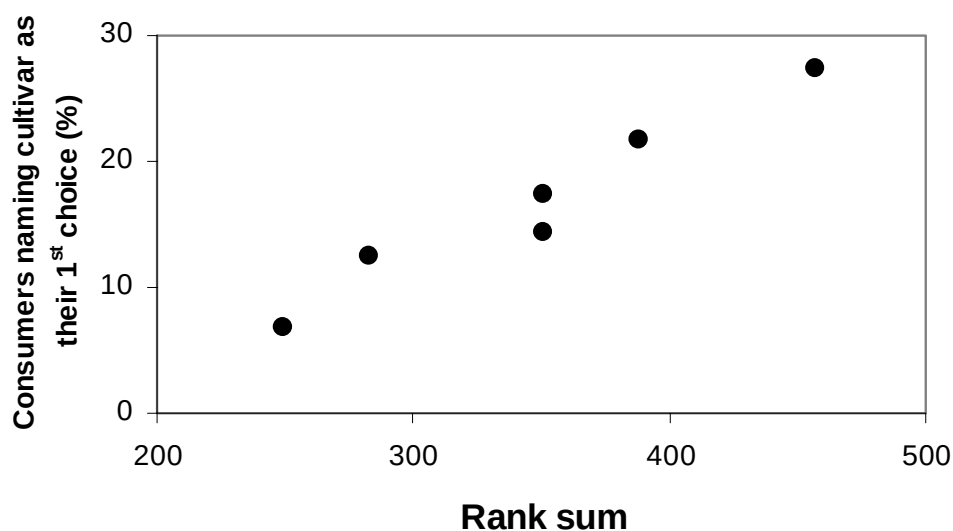


Figure 1: Relationship between first preference choice (%) and rank sum for cultivars evaluated by consumers at Meatu.

the most). Cluster 3 was comprised of cultivars that were most preferred by the largest percentages of consumers (on average 47% consumers preferred these the most), and consisted of Polista and SPN/0 from both years and Sinia B for year 2000.

Considering cultivar and seasonal differences, all Polista and SPN/0 cultivars, were in cluster 3 and all Mzondwa and Serena cultivars, were in cluster 1. Therefore, these cultivars had similar sensory characteristics

even though they were grown at different locations and seasons. However, certain cultivars appear to differ in sensory characteristics from year to year and with location, for example Sinia B was in cluster 3 in 1998 but generally in cluster 1 in 2000. Similarly, the same was noted for Ngikuru A. For some cultivars (Ipembe, Ngosha, Bukoli, and Hudi Shinyanga), it was not possible to draw conclusions because they were only tested once.

Table 2: Consumer preference (based on first choice preference) of sweetpotato cultivars evaluated at Mwanza, Meatu and Misungwi Values in brackets refer to the percent of consumers for whom the cultivar was their first preference.

Liking	Mwanza		Meatu		Misungwi	
	1998	2000	1998	2000	1998	2000
1 (most)	Polista (54)	SPN/0 (56)	SPN/0 (77)	Polista (79)	Ngikuru (57)	SPN/0 (57)
2	Sinia B (52)	Sinia B (47)	Ngosha (51)	Sinia B (67)	SPN/0 (45)	Sinia B (52)
3	SPN/0 (42)	Polista (39)	Polista (42)	SPN/0 (47)	Polista (36)	Polista (50)
4	Mzondwa (28)	Mzondwa (8)	Serena (19)	Serena (5)	Toniki (30)	Bukolu (14)
5	Bilagala (18)	Bilagala (6)	Sinia B (6)	Sinia B (26)		Hudi Shinyanga (6)
6 (least)			Ipembe (3)		Nguruka (14)	Ngikuru (3)

Figure 2: Dendrogram illustrating hierarchy of clusters of sweetpotato cultivars with respect to their sensory attributes.

Where:

M = Mzondwa, SP = SPN/0, Sin = Sinia B, Ser = Serena, B = Bilagala, P = Polista, Ngik = Ngikuru, Mwz = Mwanza, Mis = Misungwi, Mtu = Meatu.

Principle component analysis (PCA) was used to evaluate the relationship between the cultivars tested in each season and region (figures 3 and 4). PC1 and PC2 accounted for 44% and 34% of the variability respectively. The clusters are clearly divided into three groups with cluster 2 being the most distinct (figure 3). Boundaries drawn to each outer point in each cluster are included to assist in

the interpretation. Cluster 1 is predominantly in the left-hand quadrant, cluster 2 in the upper right-hand quadrant and cluster 3 in the lower left-hand quadrant. Comparison with Figure 4 confirms the findings described above. Thus, cluster 1 is mostly associated with cultivars that score low for the majority of the sensory attributes. Cluster 2 is associated with sweetpotatoes that score

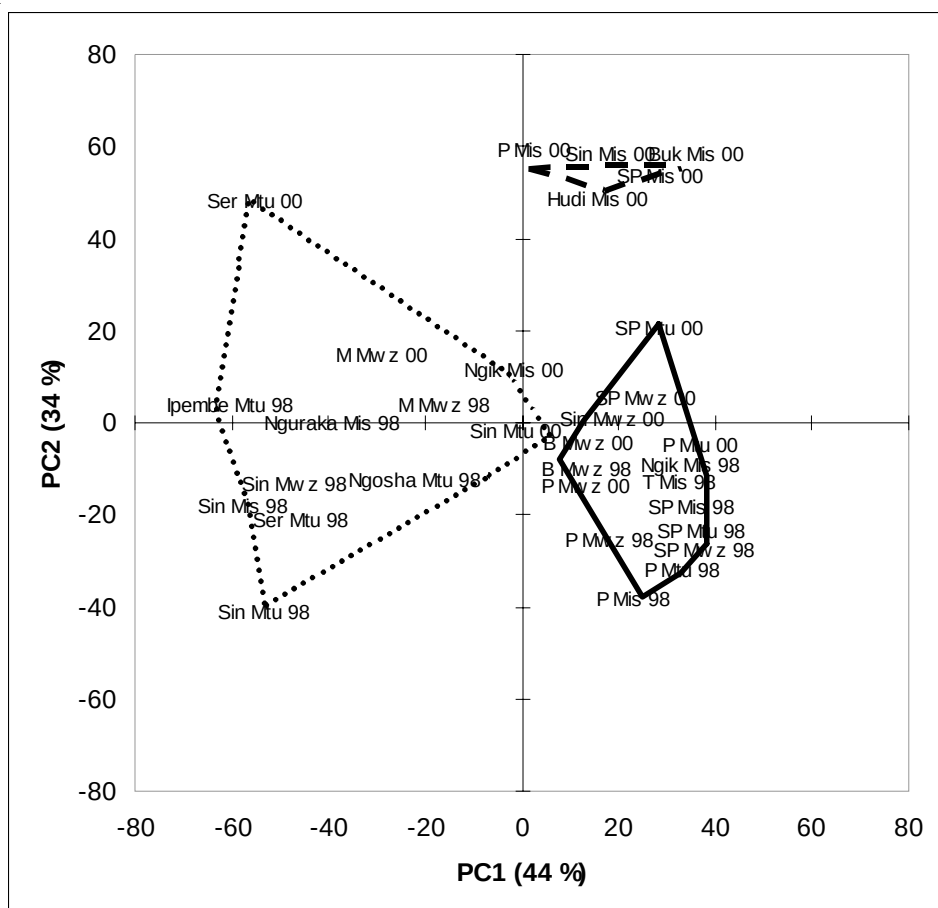


Figure 3: Principal component plot showing spacing of sweetpotato cultivars.

Where:

M = Mzondwa, SP = SPN/0, Sin = Sinia B, Ser = Serena, B = Bilagala, P = Polista, Ngik = Ngikuru, Mwz = Mwanza, Mis = Misungwi, Mtu = Meatu.

Cluster 1 = cultivars within the dotted line;

Cluster 2 = cultivars within the broken line;

Cluster 3 = cultivars within the continuous line.

Points are not included but would be located at the centre of each cultivar name in the plot

Boundaries illustrate the extent of each cluster.

higher for stickiness, texture, chewiness, internal colour, external colour, appearance and odour. Cluster 3 is related to sweetpotato that scores highly for internal and external colour, appearance, odour, sweetness, taste and starch.

Samples of the same cultivar tended to be clustered together. SPN/0 and Polista were in the right hand quadrants in both years while Mzondwa and Serena were consistently in the left-hand quadrants. This implies that for these cultivars, the sensory characteristics are broadly similar from year to year and not

influenced by location where they were grown. Sinia B, however, was in the lower left-hand quadrant in 1998 but in the right hand quadrant in 2000. The cultivars from Misungwi in 2000 were generally more sticky, chewy and scored higher for texture. It is not clear why these cultivars differed, although climatic differences and differences in storage by the traders are likely to have contributed.

Developing a model for selecting optimum sensory characteristics for selection for sweetpotato. Screening programmes often

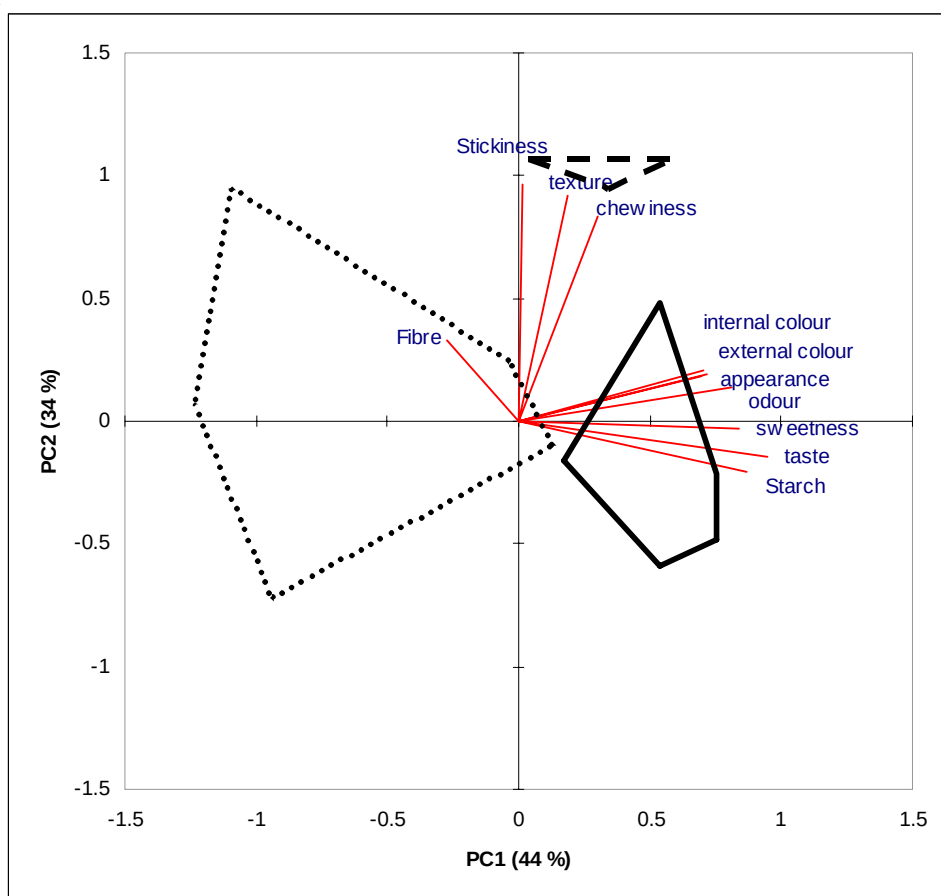


Figure 4: Principal component plot showing relationship of clusters with respect to the sensory attributes.

Where: Cluster 1 = dotted line; Cluster 2 = broken line; Cluster 3 = continuous line.

consider a large number of cultivars, so that any method that simplifies the assessment would be advantageous. We therefore wished to determine what was the minimum number of sensory characteristics that we could consider while still being able to distinguish between the clusters of cultivars.

Stepwise discriminant analysis (functions 1 and 2 account for 76% and 24% variance respectively) indicated that starch and stickiness were the optimum sensory attributes for distinguishing between the clusters. The discriminant model correctly classified 16 out of 20 cultivars.

Since only two sensory attributes were used in the model and sensory testing is fairly subjective, a simple scatter plot of these attributes (figure 5) was used to simplify cultivar selection. Cluster 3 is in the top left-

hand quadrant, cluster 1 is in the bottom left-hand quadrant and cluster 2 is in the top-right quadrant. The dotted lines (arbitrarily drawn by the authors) represent the lower and maximum limits for starch and stickiness respectively. Hence, cultivars might be considered to be the most preferred if the score for starch is 48 or greater and the score for stickiness is 42 or less.

Case study 2: Changes in sensory characteristics during shelf-life studies. NRI and partners have used sensory panels to investigate changes in the sensory characteristics of five sweetpotato cultivars (Kemb10, SPK004, KSP20, Yan Shu 1 and Zapallo) during storage under tropical conditions (van Oirschot et al., 2003). A QDA (Meilgaard et al., 1987; Bainbridge et al., 1996,

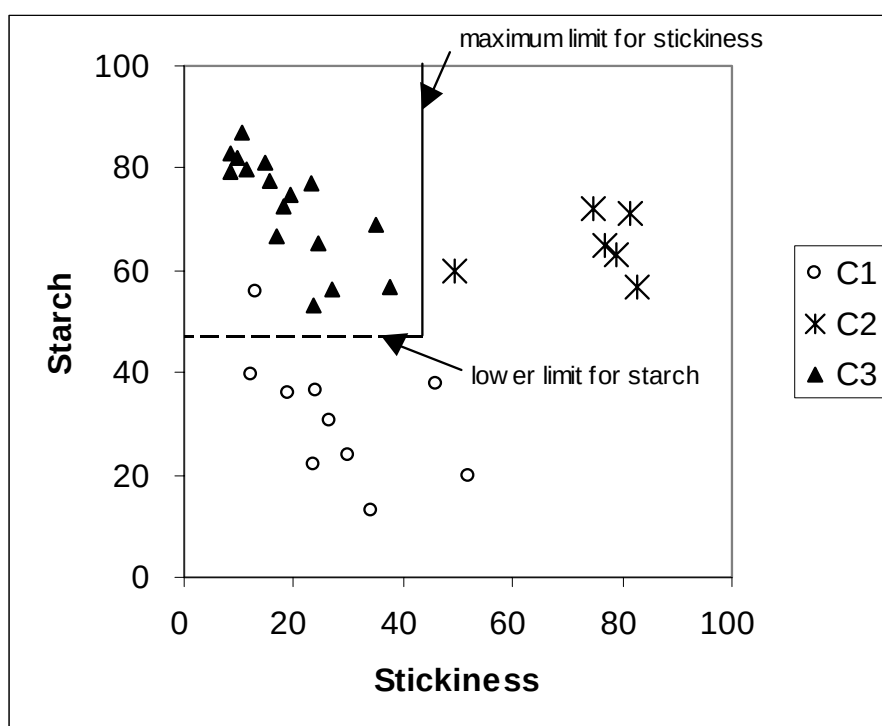


Figure 5: Scatter plot of starch and stickiness to illustrate limits for starch and stickiness when selecting sweetpotato cultivars that are preferred by consumers.

Where C1 = cluster 1, C2 = cluster 2 and C3 = cluster 3, dotted lines illustrate boundaries for cluster 3 (most preferred cultivars).

Tomlins 1998) panel used nine descriptors for sweetpotato which were floury, smooth, soft, chestnutty, sweet, fibrous, grainy, moist and discoloration. There were significant differences observed among the cultivars profiles. PCA (figure 6) revealed two principal components that explained 90% of the variation. PC1 explained 72% and correlated with textural properties, and PC2 explained 18% of the variation and correlated with flavour components. The results suggest that differences between sweet potato cultivars are mainly determined by textural components while storage had the most effect on the sweet and chestnutty characteristics. Of these differences, cultivar differences were greater than those occurring during storage.

Farmer testing of sweetpotato. Sensory panels are normally only recommended for use by trained panellists who assess the product in

an environment where sample preparation, lighting and temperature are controlled. However, in adaptive research in rural areas, farmers views need to be taken into account (Van Oirschot and Tomlins 2000). Therefore, panels suitable for use by farmers in rural locations were devised (Anon 2002; Tomlins *et al* 2003c). The simple approach was part sensory and part hedonic. Sweetpotato from either pit or clamp stores were tested in this study. The roots were cooked in boiling water at the farm until soft. A total of 56 farmers scored the roots from the stores from their farm using the score sheet in Table 3.

Cluster analysis indicated three groups with respect to the sensory attributes with either, high, intermediate or low scores. The PCA, accounting for 84% of the variation, is shown in figure 7. The three clusters line in the same plane at PC1 which accounted for 71% of the variation. Cluster 2 is most

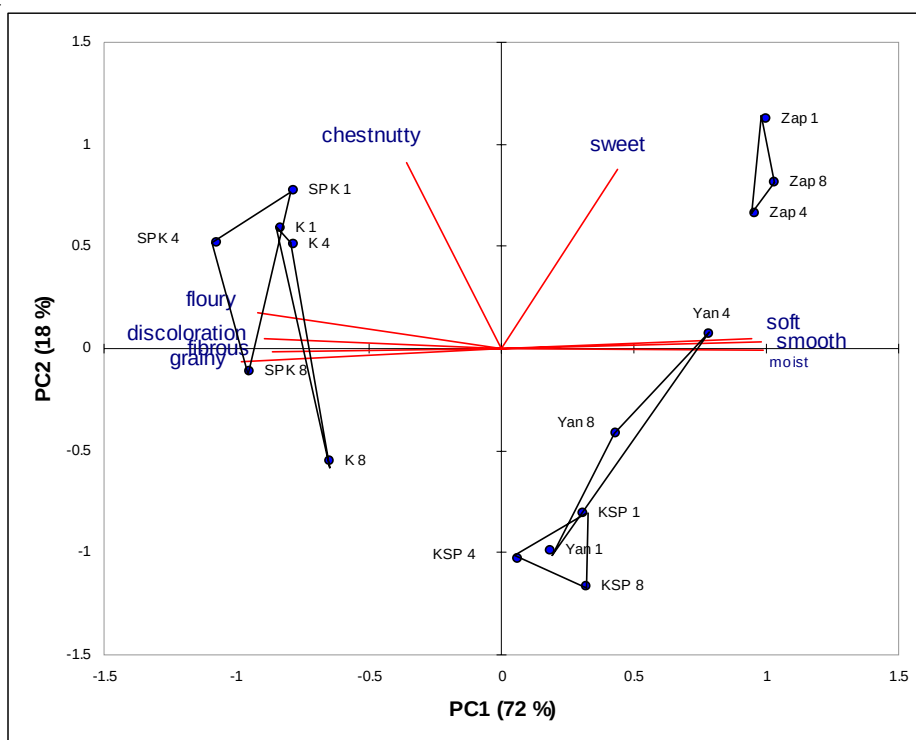


Figure 6: Sample scores of five cooked sweet potato cultivars on the first and second principal component after PCA analysis of the sensory profiles. Cultivars presented are Zap = Zapallo, Van = Van Shu 1, KSP = KSP 20, K10 = Kemb 10, SPK = SPK 004, and the numbers refer to the storage times of 1,4 or 8 weeks after harvest.

Table 3: Used a simplified panel. Farmers prepare the samples and access using the simplified score sheet.

	Very bad	Bad	Medium	Good
Very good				
Appearance				
Sweetness				
Flouriness				
Acceptability				

positively associated with the sensory attributes and cluster 3 the least. The variability within each cluster was in the same direction of PC2 which accounted for 13% of the variation.

Although the cluster did not significantly differ with respect to the type of store (pit or clamp), they did differ ($P = 0.001$) in the proportion of rotten roots in the stores. The proportion of rotten roots was associated with stores that were exposed to direct sunlight or that had been flooded with rain water. Therefore, the sensory attributes could be influenced by how the stores were managed and situated.

Conclusions

The majority of consumer preference studies is undertaken in developed nations and is directed towards high income consumers. This paper has shown that appropriate consumer preference and sensory evaluation approaches can have an important role to play in sweetpotato research, production and marketing for low-income consumers in developing countries. This can lead to increased uptake by these groups.

In consumer preference, by interviewing sufficient consumers (100 or greater) it is possible to evaluate the views of the low income consumers and how they make a choice. The use of simplified consumer testing methods (only to chose the most preferred cultivars out of those offered) can facilitate consumer preference studies where people have minimal education such as in rural areas and the urban poor. The application of appropriate statistical tools (principal

component analysis, discriminant analysis) can enable models to be developed that enable consumer preference to be combined with sensory panels so that sensory results can be used as a low cost approach for predicting consumer preference of sweetpotato cultitvars. The study showed that consumer preference of some sweetpotato cultitvars varied from season to season implying that new cultivars should be evaluated over more than one season.

Sensory evaluation can used to assess the effect of changes during shelf-life of sweetpotato cultivars using Quantitative Descriptive Analysis, while simpler, less controlled methods could be used by farmers in rural areas of East Africa so that their views could be taken into account.

Consumer preference and sensory testing has an important part to play in sweetpotato research and marketing. The application of consumer preference to low-income groups is necessary to increase the success of research and marketing strategies. In particular, the new orange fleshed sweetpotato varieties that are being introduced for reducing vitamin A deficiency in Africa require extensive consumer preference testing.

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The potential for storage of fresh sweetpotato under tropical conditions: Evaluation of physiological changes and quality aspects

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Abstract. This paper presents the results of two years of trials carried out on-station at Lake Zone Agricultural Research and Development Institute, Tanzania and gives recommendations for simple and low cost storage of fresh sweet potato. The optimum conditions for long term storage of sweet potato are well known, but little is known about the conditions in simple storage structures or if it is possible to influence them. To evaluate this, five different treatments were assessed. These were: effect of cultivar (SPN/0, Polista and Sinia B); level of root damage; lining with dried grass; ventilation; and store design (pits or clamps). Over a period of 18 weeks, the physiological changes of the roots in the stores were monitored via oxygen and carbon dioxide levels, relative humidity, temperature and root weight. The quality of the stored roots was assessed by sensory evaluation, external appearance and estimated market value. High temperatures and high weight loss of the roots indicated deterioration during storage. This was most strongly associated with storing damaged roots as opposed to good quality ones. Store type (pit or clamp) or ventilation did not have a consistent effect on shelf-life and suggests that any combination of these designs can be used. Sensory properties may change during storage and acceptable characteristics were found up to 12 weeks of storage. Stored roots may taste sweeter than freshly harvested roots. Success of storage, however, is also

determined by other factors than just store design and this is discussed.

Introduction

Sweet potato roots can be stored under controlled environments for several months. The optimum conditions for long term storage of sweet potato are well known and in temperate areas in the United States, roots can be stored for up to one year (Picha 1986). Little is, however, known about the conditions in simple storage structures or if it is possible to influence them. In tropical areas where sweet potato consumption is an important part of the diet, the post-harvest shelf life of roots is short. An understanding of post-harvest changes in the commodity may help to improve store design and so make sweet potato available over longer periods of time. This may be a beneficial for food security or marketing roots out of season.

In some cooler areas of the tropics, fresh storage is currently practised and a number of traditional storage technologies have been reported. These include the use of pits, clamps (piles, mounds, heaps), cellars, bulk bins or just leaving roots in the ground. Information about environmental and physical changes (temperature, humidity, storage period and weight loss) during storage is, however, sparse. Lining stores with dry plant material, such as dried grass (NRI/NARO 1996; Hall and Devereau, 2000), bamboo

(Gooding and Campbell, 1964), with ash (Woolfe 1992) or sand (Sandifolo *et al.*, 1998) has been described as having a beneficial effect upon storage. The function of these materials is, however, not clear. In the highlands in south west Tanzania sweet potatoes are traditionally stored in pits under banana trees.

This paper summarises the results of two years of storage trials carried out at the Lake Zone Agricultural Research and Development Institute, Tanzania and gives recommendations for simple and low cost storage of fresh sweet potato roots. The research aimed to gain a better understanding of how store design affects the atmospheric conditions around the fresh produce, and how the atmospheric conditions in their turn affect quality aspects of the fresh roots during storage. The factors tested included: three cultivars, two levels of ventilation, pit and clamp types of store, lining with dried grass and the effect of damage to roots.

Materials and Methods

Trials were carried out with 36 stores in 2000 and 24 stores in 2001; each with a unique combination of design factors. Five different treatments were assessed: cultivar (Polista, Sinia B and SPN/0); ventilation where stores with extra ventilation contained six ventilation pipes, others two pipes; lining with dried grass (which was folded into bunches of 10 cm diameter and placed inside the pits or outside the clamps); store type using both pit and clamp types of store (Round pits were dug in the soil of about 0.6 m in diameter and 0.6 m depth. Clamps were built with the roots); and damage treatment that was carried out by rolling a sack of roots 10 times. This treatment simulates damage that occurs during handling and transport of roots which is known to cause 'skinning injury' and was only used in 2000.

Each store contained 70 to 100 kg roots of similar quality. Over a period of 18 weeks of storage, the physiological changes of the roots in the stores were monitored by

measuring root weight, dry matter content, oxygen and carbon dioxide levels, relative humidity and temperature. The quality of the stored roots was assessed by "Estimated Market Value", sensory evaluation and external appearance, which included sprouting, shrivelling, rotting and weevil infestation.

During storage the conditions inside the stores were monitored (temperature, relative humidity (RH), oxygen and carbon dioxide). Temperature and relative humidity were determined using a probe (Hanna Instruments, Portugal), or Tiny Talk data loggers (Gemini, Chichester, UK) that were inserted into the store at least every week for 10 minutes. Gas samples were taken in duplicate at regular intervals (at least every week) from each store via tubing (Tygon 3603 (BDH), 3 mm). The measurements were made using a CO₂ meter and an O₂ meter (Anagas CD 98 and Oxycheck 2, David Bishop Ltd, UK).

Physiological characteristics were recorded at 0, 2, 4, 8, 12, and 18 weeks when stores were opened and inspected. Weight loss was determined by taking ten randomly selected roots per store labelling them and recording their weights every time the stores were opened. In addition rotten roots were removed during opening of the stores, and their total weight was recorded as a percentage of initial weight of roots stored. Dry matter contents were determined for three roots per store using both cooked and uncooked roots. To determine dry matter contents roots were sliced and dried for 48 hours in an oven at 80°C.

Respiration rates were measured at 25°C. Single roots were weighed and placed in a 3 L jar. Air samples were removed at intervals from each jar through a rubber septum using an air-tight syringe. Levels of carbon dioxide and oxygen were measured by gas chromatography using a molecular sieve (to separate carbon dioxide from oxygen/nitrogen) and poropak column (to separate oxygen and nitrogen) and a thermal conductivity detector.

The quality of roots was assessed at 0, 2, 4, 8, 12, and 18 weeks of storage. A sample of 20 randomly selected roots was used. To determine the "Estimated Market Value" the roots were divided into two heaps. Ten consumer panellists then estimated the value of the roots, in relation to standard heaps, consisting of roots bought on the market that day. All heaps of roots were weighed, and thus the price per kg was calculated for each heap of roots. For External Assessment all 20 randomly selected roots were scored by three scientists for breaks, cuts, skinning injury, shrivelling, rotting, weevil infestation and sprouting.

Sensory evaluation was carried out by an expert taste panel of 10 panellists. Equally sized pieces (3-5 cm) were boiled for approximately 20 minutes and until the texture assessed by a fork was considered correct for eating. Each panel member scored each store-sample for pre-determined important characteristics by placing a mark on a 10.5 cm line. Characteristics included: appearance, colour (inside and outside), taste, smell, sweetness, flouriness, texture, chewiness, stickiness and acceptability. Panellists were presented with three or four randomly selected samples labelled with a random number. Three sessions (morning, noon and afternoon) were conducted each day.

Statistical analyses were carried out using Genstat (Rothamsted, UK). Due to the incomplete design in 2000, the significance levels were calculated using type II and type III sums of squares. In year 2001 analysis was carried out using ANOVA. It only included only the main effects (store type, cultivar, ventilation and lining) because of the lack of replication.

Results

Physiological changes. Table 1 indicates which of the design factors had a significant effect ($P < 0.05$) upon physiological changes of the roots during the storage period. The average weight losses for stored roots were up to 4% (2 weeks), 7% (4 weeks) 15% (8

weeks) and 28% after 12 weeks (Figure 1). Weight losses were reduced in year 2000 when stores were lined. Significant effects were observed in weeks 4, 8 and 12, while in year 2001 the lining treatment significantly increased weight loss during the whole storage period ($p < 0.05$). In week 8 significant higher weight losses were observed in pits ($P < 0.05$).

Dry matter content was measured for both the fresh and cooked roots sampled during storage. The pattern for both was similar. Cultivar, and to a lesser extent lining, were the factors that influenced dry matter content (Figure 1). Polista has the highest dry matter content when cooked ($P < 0.05$; 41 to 44% compared to 37 to 41% of the other cultivars and for fresh roots. In unlined stores the dry matter content was significantly lower in week 12 ($p < 0.05$).

The CO_2 concentration in the stores varied between 0.1% and a maximum of 13%. It increased during storage and the increase was in stores that were not lined and not ventilated. For lined stores (Figure 2) CO_2 levels increased from an average of 1.6% in the first four weeks of storage to 3.3% in the last four weeks, while unlined stores the increase was from 2.3% to 5.3%. Stores with the cultivar Sinia B showed high levels of CO_2 . On average the levels did not rise above 7%.

The oxygen concentration in the stores varied between 15 and 21%. Overall, it followed an inverse response to CO_2 and the significant differences with respect to lining and ventilation were similar. Cultivar differences up to week 8 were noted where the concentration was least for Sinia B cultivar and highest for Polista.

The temperature (Figure 2) was about 3°C degrees higher in stores with damaged roots in the first two weeks of storage ($P < 0.01$). This may be due to the higher metabolic activities of roots within the stores. The higher respiratory activity among the roots may have been due to wounding or even to rotting. Later during the storage period the temperature in stores with damaged roots was similar to other stores. Stores with cultivar

Table 1. Store design factors that had a significant effect ($P < 0.05$) upon physiological changes of the roots during storage in on-station trials in the Lake Zone of Tanzania.

Physiological changes	Store design factors with significant effect	Design effects on physiological changes
Weight loss	Lining with grass; Clamp/pit	Lower weight loss when stores were not lined. Store type affected weight loss in week 8.
Dry matter cooked roots	Lining with grass; Cultivar	Polista has the highest dry matter content when cooked ($P < 0.05$; 41-44% compared to 37-41% in other cultivars). Lower dry matter where there is no lining.
Dry matter uncooked roots	Cultivar	Polista has the highest dry matter content for fresh roots
Oxygen in store	Cultivar; Lining with grass; Ventilation	Oxygen levels were higher in stores with extra ventilation and grass lining. Stores with cultivar Sinia B showed low levels of oxygen
CO ₂ in store	Lining with grass; ventilation	CO ₂ levels were lower in stores with extra ventilation and with grass lining. Stores with cultivar Sinia B showed high levels of CO ₂ .
Temperature	Damaged roots; Ventilation	Temperature was about 3 degrees higher in stores with damaged roots in first 2 weeks ($P < 0.01$). increased ventilation reduced the temperature
Relative Humidity	Ventilation	The relative humidity was higher in stores with little ventilation (2 pipes 80-95%) than in stores with increased ventilation (6 pipes; 70-80%)
Respiration rate	Cultivar	Higher rate of respiration for Polista (73.8 ml CO ₂ /Kg/h) compared to SPN/0 and Sinia B (45.5 and 43.9. ml CO ₂ /Kg/h). Polista could be more prone to anaerobiosis in sealed store.

SPN/0 recorded a lower temperature for the first four weeks of storage than the cultivars Polista and Sinia B. Ventilation only affected the temperature significantly after one week of storage, where two pipes ventilation resulted in higher temperatures than use of six ventilation pipes.

The relative humidity (Figure 2) was higher in stores with two pipes ventilation (80-95%) than in stores with six pipes ventilation (70-80%). This was highly significant after 1, 2, 7 and 14 days. After three weeks the humidity in the stores with two pipes dropped to under 80%. Respiration

experiments indicated that Polista had a significantly higher rate of respiration (73.8 ml CO₂/Kg/h) than SPN/0 and Sinia B (45.5 and 43.9. ml CO₂/Kg/h), with no significant difference between the latter two cultivars. It would be predicted that Polista is less suitable for long-term storage than the other two cultivars. It would be expected that Polista be more prone to anaerobiosis within a sealed store (Rees 2002). This is however inconsistent with the O₂ and CO₂ measurements in the stores where Sinia B had the highest levels of CO₂.

Quality changes. Table 2 indicates which of the design factors had a significant effect ($P < 0.05$) upon quality aspects of the roots during the storage period. The estimated market value was mostly affected by choice of cultivar ($p = 0.009$). SPN/0 had the highest value per kg and was between 60 and 50 TSh/kg (exchange rate: US\$1.0 = 775 TSh). This is in agreement with the findings of Rwiza *et al.* (2000) who found that the consumers have a preference for the cultivar SPN/0. Sinia B was

valued lowest per kg. At this stage in storage the effect of damage was not significant ($p = 0.056$). During storage the estimated market value declined for all roots and was much steeper for damaged than for undamaged roots. The damaged roots were valued at 35.8, 25.9 and 20.9 TSh/kg for 2, 4 and 8 weeks respectively, while the undamaged roots were valued at 51.3, 43.8 and 31.2. Roots kept in pits were valued higher than roots kept in clamp stores and after eight weeks the

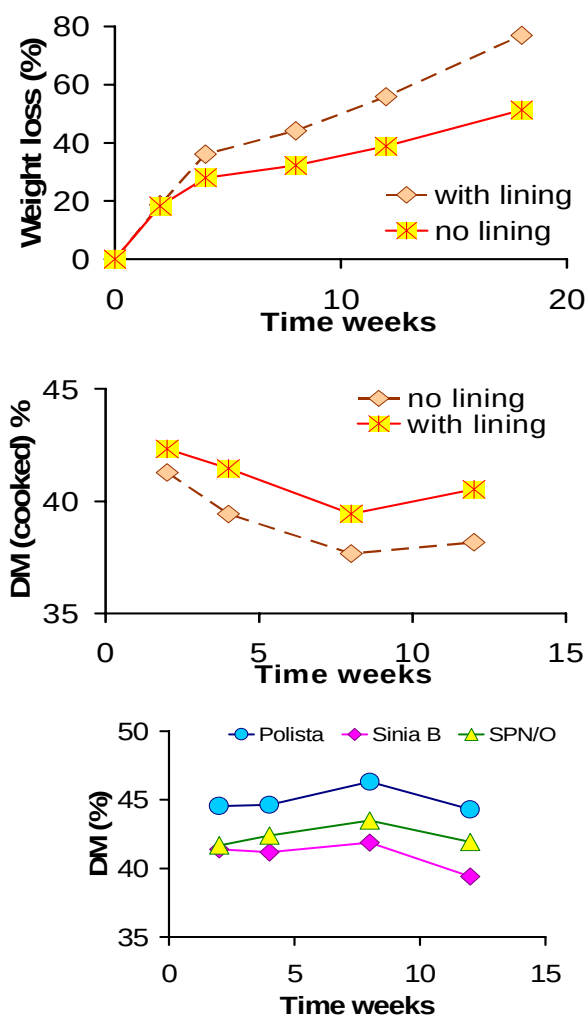


Figure 1: Changes in weight loss and dry matter (DM) of sweet potatoes stored in pits and clamps in the Lake Zone of Tanzania. Figures show effect of lining of stores with grass and variety of sweet potato.

Table 2: Design factors with a significant effect ($P < 0.05$) upon quality aspects of sweet potato roots during the storage period in on-station trials in the Lake Zone of Tanzania.

Quality Aspects	Store Design factors with significant effect	Design effect on Quality Aspects
Estimated Market Value	Damaged roots; Lining with grass	Higher Estimated Market value for undamaged roots after 2-8 weeks storage. Roots from lined stores and clamps had a lower Estimated Market Value
Sprouting	Ventilation; Lining with grass; Cultivar	Most sprouts in stores with no lining, low ventilation, pits. The cultivar Sinia B had significant more sprouting.
Shrivelling	Lining with grass	The levels of shrivelling, expressed as a score during external evaluation, were significantly higher for roots from stores lined with dried grass.
Rotting	Damaged roots; Clamp/pit	Roots in clamps had a higher percentage rotted roots than roots from pits. Also stores of which the roots had a damage treatment had higher levels of rotting.
Deep weevils	Lining with grass	There was significantly more deep weevil (<i>Cylas</i> spp.) infestation in stores with dried grass lining.
SE (Sensory Smell, taste acceptability)	Cultivar; Damaged roots; Lining with grass	Cultivar, damage and lining had significant Evaluation) negative effects on smell, taste and acceptability, especially after 2 and 4 weeks.
SE: Appearance, Colour (inside and outside)	Cultivar; Damaged roots; Lining with grass	Cultivar had significant effect on colour and appearance, with SPN/0 kept the best appearance during storage. Damage and lining affected the attributes in week 2 to 4.
SE: Sweetness and flouriness	Cultivar; Damaged roots;	Sweetness increased for the cultivars SPN/0 and Polista during the first weeks of storage. Sinia B was much less sweet.
SE: Texture, chewiness and stickiness	Cultivar; Damaged roots; Lining with grass	Cultivar had a significant effect on texture and chewiness. Damage resulted in lower texture in week 0, 2 and 4. Lining reduced chewiness of roots in the first 2 weeks.

estimated market value for roots from clamps was a third lower than of pit stored roots (20.8 and 31.8 Tsh/kg).

Roots in clamp stores were also more susceptible to rotting (Figure 3). Statistical analysis revealed that two factors significantly affected rotting: damage and type of store. Pit storage resulted on average in 11% rotten roots after four weeks and 25% after 12 weeks, while clamp storage resulted on average in

28% rotten after four weeks and 35% after 12 weeks. Damage affected rotting and 27% of the damaged roots were rotten after four weeks while 35% were rotten after 12 weeks. Of the undamaged roots 12% were rotten after four weeks and 35% after 12 weeks. Data for estimated market value and rotting were only analysed for the year 2000. Sprouting, assessed during the external assessment of 20 randomly selected roots, started to appear

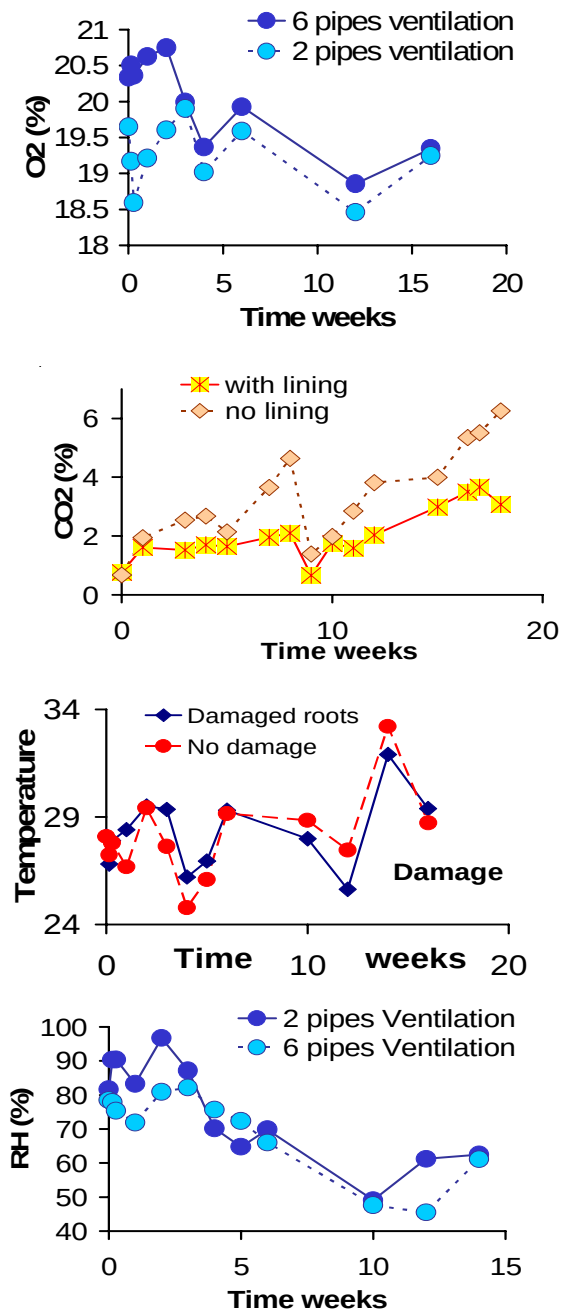


Figure 2: Changes in environmental conditions with pit and clamp stoes of sweet potato during storage in the Lake Zone of Tanzania. Figures show effect of ventilation, lining and damage on selected environmental conditions (oxygen level, carbon dioxide level, temperature and relative humidity).

after two weeks. Many of the stores showed significant sprouting, sometimes even large green patches of green leaves could be seen outside of the stores. Susceptibility to sprouting was significantly affected by

cultivar ($p < 0.005$ in week 4) and Sinia B was most susceptible for it (Figure 3). Less sprouting occurred when stores were lined with dried grass. Pits had a higher rate of sprouting than clamps. There was a

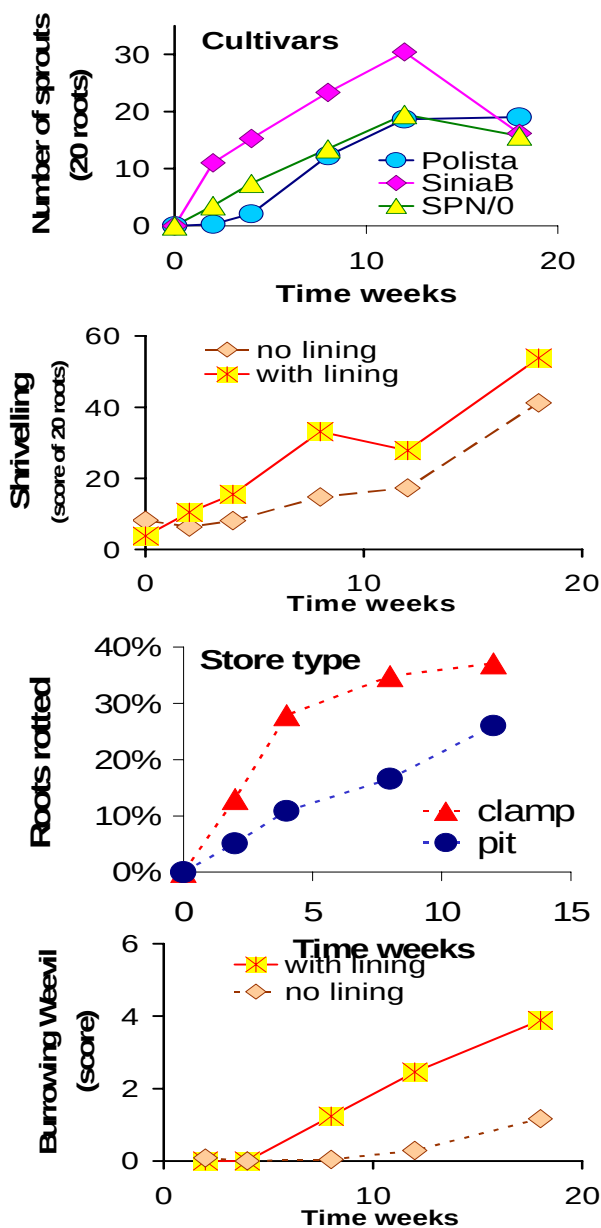


Figure 3: Changes in quality of sweet potato roots in pit and clamp stores in the Lake Zone of Tanzania. Figures show effect of variety, lining and store type on sprouts, shrivelling, rotting and burrowing weevil.

relationship between the level of sprouting and the level of rotting (Figure 4).

The levels of shrivelling, expressed as a score during external evaluation, were significantly higher for roots from stores lined with dried grass (Figure 3). The trend for shrivelling had very low occurrences up until week 12 after which shrivelling and rots dramatically increased, the greatest increase being in the lined stores (Figure 3). The levels of shrivelling increased during storage for all stores. Store design did not have a consistent effect on the level of shrivelling. Slightly more shrivelling was observed with grass lining, and ventilation had a slight effect in the first eight weeks. Polista was overall slightly more susceptible to shrivelling than the other varieties.

There was significantly more deep weevil (*Cylas* spp.) infestation in stores with dried grass lining at 8, 12 and 18 weeks ($p < 0.05$). Sweet potato weevil also increased more in the lined stores but this increase occurred from week 4 onwards whereas for unlined stores, the increase was delayed until after week 12 (Figure 3).

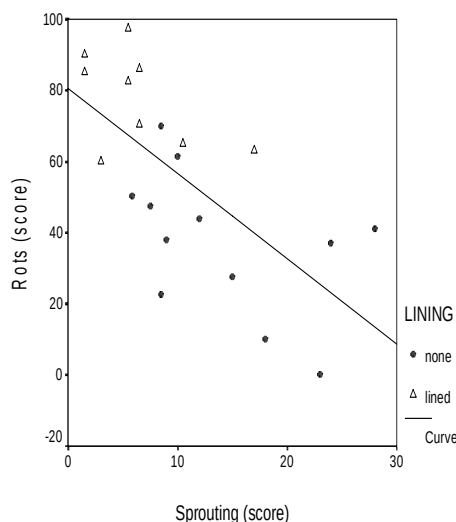


Figure 4: Relationship between rots and sprouting in sweet potato stored in pits and clamps with and without grass linings in the Lake Zone of Tanzania.

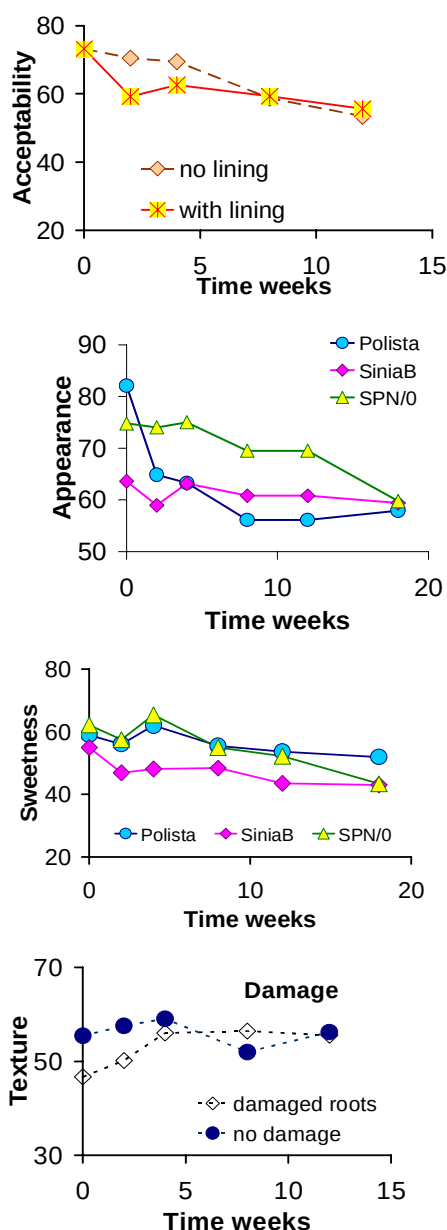


Figure 5: Changes in selected sensory properties of sweet potatoes stored in pits and clamps in the Lake Zone of Tanzania. Figures show effect of lining, variety and damage on sensory properties over time.

Taste, smell and acceptability were affected by cultivar, damage and lining especially after 2 and 4 weeks of storage. Cultivar had a highly significant effect after 4 weeks ($p < 0.005$). Taste scores increased for

SPN/0 since harvesting from 72 to 73.4 while it had decreased for Sinia B from 65 to 50.7. For Polista a slight decrease in scores was noted from 69 to 67.6. A similar pattern was observed for smell. Damage only affected taste, smell and acceptability at 0 ($p < 0.05$) and 2 weeks ($p < 0.01$) and damaged roots scored lower for all sensory tests. Grass lining had a significant negative effect on these sensory characteristics at 2 and 4 weeks.

Cultivar had significant effect on the inside and outside colour and appearance of the roots, with SPN/0 keeping the best appearance during storage (Figure 5). Undamaged roots gave a significant higher score for these characteristics immediately after harvesting ($p < 0.001$) and in week 8 ($p < 0.05$). Lining reduced the scores from appearance and colour significantly ($p < 0.01$) in week 2 (Figure 5).

Cultivar had significant effects on the sweetness and flouriness of the roots (Figure 5). This was significant at four weeks for flouriness ($p < 0.05$) and sweetness ($p < 0.005$). Both SPN/0 and Polista developed these tastes well during storage: a small reduction in sweetness after two weeks, increasing to scores higher than at harvesting time at four weeks. For Sinia B these characteristics did not develop so much during storage.

Stickiness, texture and chewiness tended to increase during storage. Stickiness was not affected by any of the design factors. Cultivar had a significant effect on texture and chewiness in weeks 2, 4 and 8. The scores for texture and chewiness of Polista decreased during storage, while it increased for SPN/0. Damage resulted in lower texture and chewiness scores in weeks 2 and 4 (Figure 5). Lining reduced chewiness of roots after two weeks.

Discussion

In order to determine the best strategy for storage it is important to determine which characteristic is most important for root quality. Previous work has indicated that weight loss is very important to determine the

shelf life of roots (Rees, 2003b). Van Oirschot *et al.* (2000b) estimated that a rough guidance to saleability of roots is that with up to 20% weight loss sweet potato roots are still saleable. When the level of weight loss was 35% or greater they will become unmarketable. The weight losses recorded here, suggests that after 12 weeks, when weight losses are up to 12% roots can still be marketed. The estimated market value of the roots may decrease substantially during storage, and the value was less than 50% after 8 weeks storage. Thereafter the values were too low and missing data meant that the statistical analysis was not possible. A top ten of estimated market value roots included mainly undamaged roots (8), of the pit type (7). Six out of 10 had no lining and other 6 out of 10 no ventilation. The cultivar Sinia B was in 6 of the top ten stores, while SPN/0 only appeared once.

The results suggest that weight loss can be limited by not lining the stores. As weight loss is also affected by relative humidity it can be argued that reduced ventilation would lead to increased relative humidity, leading to reduced weight loss.

Ventilation seems especially important during the first two weeks of storage. This would appear to prevent too large an increase in temperature and build up of carbon dioxide, which would lead to anaerobic respiration. Later ventilation should be reduced, as it may reduce the relative humidity and increase water loss from the roots and lead to shriveling.

The temperatures measured and the RH should be high enough for wound healing to take place (van Oirschot *et al.* 2002). However, old wounds of damaged roots have a higher rate of water loss than the native periderm (van Oirschot *et al.* 2000a). Therefore it is recommended to keep damage as low as possible.

The dry matter content of roots is an important quality characteristic for sweet potato in East Africa, and has resulted in specific breeding programmes (Rees *et al.* 2003a). High dry matter after storage may however indicate desiccation. This may have

been the case in the lined stores with dried grass that had an average DM of % in comparison with unlined stores. Lining may have contributed to lower RH, and therefore increased rate of water loss and reduced levels of wound healing, which resulted in higher levels of desiccation. High respiration levels of carbon dioxide in the stores and high weight loss for the roots indicated deterioration during storage. This was most strongly associated with damaged roots as opposed to good quality ones. Although a high dry matter content is a plus, it may also indicate water loss of the roots and shriveling. Good roots sprouted often. The question is whether sprouting is desirable or not.

Sprouting was in general an indication of good quality roots. Figure 4 illustrates the significant ($P=0.001$, $R=-0.670$) inverse correlation between rotten roots and sprouting. This illustrates the practical visual importance of sprouting in the stores because this indicates healthy roots as opposed to rotten/shrivelled ones. The points in the figure are identified as either coming from a lined or unlined store and also shows that roots are healthier in unlined stores. A related study monitored the effect of store type (pit or clamp), shade (shaded under a tree or located in direct sunlight) and pre-treatment with chemical fungicide on sweet potato storage. Locating the stores in the shade under a tree improved market value. Store type was found to be not important (Tomlins and Ndunguru 2001). On farm studies revealed that farmers liked pits because of safety and clamps because they were easier to build.

Sweet potato is consumed as a food source and so the sensory properties of the produce is very important. These studies have shown that good quality roots can still be obtained after storage.

Conclusions

The design factor with most pronounced effect on storage was lining with dried grass. Roots from lined stores had a lower estimated

market values, higher levels of shriveling and more often deep weevil infestation. Lining also increased oxygen levels and reduced carbon dioxide levels. After 12 weeks, weight losses of roots were high, and the acceptability decreased. Very good sensory properties were obtained up to four weeks of storage. Cultivar differences for storage success exist and both SPN/O and Polista can be used. Storage should only be carried out using good quality roots. Store type (pit or clamp) or ventilation did not have a consistent effect on shelf-life and suggests that any combination of these designs can be used. Some ventilation is necessary for gas exchange and to avoid build up of high levels of carbon dioxide, but high ventilation reduces the humidity. Roots in clamps more frequently showed rotting in the trials on station, but in subsequent on-farm trials they were as successful as pits.

Roots are more likely to be secure from animals (snakes, rats) in pits while clamps are easier to build, but require more materials. The positioning of stores is crucial. They must be positioned in the shade with good drainage. Cultivar had a relatively small impact on storage with polista and SPN/O cultivars leading to slightly improved shelf life. These cultivars also had significantly lower oxygen and higher volatile sulphur compounds at the 8 weeks of storage. This indicates possible differences between the cultivars with respect to curing and wound healing.

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Probiotic and prebiotic properties of lactic acid bacteria isolated from cassava fermentations

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Abstract. This work was a preliminary investigation of the putative prebiotic and probiotic properties of lactic acid bacteria (*Lactobacillus* sp., *Pediococcus* sp.) isolated from cassava and sorghum fermentations. Exopolysaccharides produced by a small number of isolates were tested for their ability to stimulate *Bifidobacterium*, but not *Escherichia coli* or *Clostridium perfringens*. At the same time, a number of isolates were screened for basic probiotic properties (resistance to stomach acidity and bile) and for production of specific anti-microbial agents. Results showed that EPS produced by some isolates was fermented by *Bifidobacterium*, but not by *Escherichia coli* or *Clostridium perfringens*. At the same time the basic probiotic properties of resistance to stomach acidity and bile could be demonstrated. Some isolates also produced anti-microbial compounds. In the present study, however, isolates producing EPS with prebiotic properties were not those producing anti-microbial compounds. Although considerable substantiation is required, isolates of lactic acid bacteria (LAB) from cassava and sorghum fermentations appear to have considerable potential as both probiotic and prebiotic ingredients in foods. These properties could be exploited either to enhance the nutritional value of existing foods, such as cassava, or in development of new food products based on traditional foods.

Introduction

The relationship between the intestinal microflora and health has been extensively studied in recent years and the importance of bacteria of the genera *Bifidobacterium* and *Lactobacillus* in promoting good health is recognised. Dietary modulation of the microflora to increase the proportion of these beneficial (probiotic) bacteria is the subject of significant research effort. Two approaches are taken: production of dietary supplements or foods, such as yoghurts, containing live cultures of probiotic bacteria and incorporation of ingredients that favour the growth of *Bifidobacterium* already present in the intestine. Such ingredients are described as prebiotics (Gibson and Roberfroid, 1995) and are substances that are not digested by humans and that are metabolised by bifidobacteria (and possibly lactobacilli), but not by other members of the gut microflora. The probiotic approach is considered limited by loss of viability of bacteria during product storage and by the more fundamental problem of introducing new strains of bacteria to an established microflora. The prebiotic approach may, therefore, be seen as preferable, but there can be digestive problems if intake is excessive. Probiotics can be combined with prebiotics, the resulting symbiotics being considered highly effective (Collins and Gibson, 1999). This study was carried out to

investigate prebiotic and probiotic properties of lactic acid bacteria from cassava and sorghum fermentations.

Materials and Methods

Isolation of extracellular polysaccharide-producing lactic acid bacteria. Model fermentations were set up using cassava, sorghum, maize and dried beans in water. Materials were purchased at local markets in London, but all were of African origin. Fermentations were incubated at 37°C and samples taken after 24, 48 and 72 hours. Samples (10g) were homogenised in a paddle-type blender and decimal dilutions, prepared in maximum recovery diluent, were plated onto MRS (Oxoid, UK) medium and, on some occasions, MRS medium with sucrose replacing glucose as fermentable carbon source. After incubation (37°C for 48 hours under anaerobic conditions), colonies developing were examined for formation of slime as a marker of EPS production.

EPS-producing colonies were purified by streaking and identity as LAB was confirmed by a negative reaction in the catalase test and by microscopic examination of Gram-stained smears. Gram-positive, rod-shaped bacteria were presumptively identified as *Lactobacillus* and Gram-positive, coccal-shaped bacteria occurring in tetrads were presumptively identified as *Pediococcus*. In some cases, fermentation profile was determined using the API 50 CHL system (bioMérieux, UK), which also permitted tentative identification to species level. The identity of two isolates was confirmed genotypically by sequencing the 16S rRNA gene.

Conditions for production of extracellular polysaccharides. The influence of fermentable carbon source was determined by visually comparing the quantity of EPS produced during growth with glucose, fructose, sucrose or maltose as carbon source. Effect of temperature was determined comparing EPS production during incubation at 30°C and 37°C. Attempts to quantify yield

in relation to cell numbers by growing cultures in MRS broth containing the four different carbon sources were unsuccessful due to isolates losing the ability to produce EPS in liquid culture.

Differential fermentation of extracellular polysaccharides. EPS was harvested from the surface of agar media, washed in Ringer's solution and pasteurised by heat. Reinforced clostridial broth containing no added fermentable carbon source was used as basal medium. Fermentation of EPS by a "cocktail" of *Bifidobacterium* species was determined using basal medium alone (negative control), basal medium containing 2% EPS and basal medium containing lactulose (a known prebiotic) as positive control. An experiment was also made with a single type of EPS in which growth of the "cocktail" of *Bifidobacterium* was compared in basal medium containing glucose and basal medium containing glucose and EPS. Fermentation of EPS by *C. perfringens*, a non-pathogenic strain of *E. coli* (555) and a non-toxigenic strain of *E. coli* serovar O157: H7 (NCTC 12990) was determined using the same basal medium. Glucose was used as carbon source in the positive control in place of lactulose, which is not fermented by these bacteria.

Tolerance of gastric acidity and bile. Isolates of LAB were grown in MRS broth to a density of ca. 10⁸ cells/ml. Tolerance of gastric acidity was determined by inoculating MRS broth at pH 2.5 with ca. 10⁵ cells/ml and incubating at 37°C for 4 hours. Microbial numbers were determined immediately after inoculation and at the end of incubation. A similar procedure was used for determination of bile tolerance, cells being exposed to 0.3% purified ox-gall bile (Sigma-Aldrich UK). A known probiotic strain of *Lb. plantarum*, 299v, was included in the study for comparison.

Production of inhibitors by isolates of lactic acid bacteria. Inhibition was tested against *C. perfringens* and *E. coli* O157: H7. LAB were grown in MRS broth, cells removed by centrifugation and the supernatants

pasteurised. Sterile filter paper discs were moistened with culture supernatant and placed on the surface of lawn plate cultures of test bacteria. After incubation for 24 hours at 37°C (*C. perfringens* in anaerobic conditions, *E. coli* in air), plates were examined for zones of inhibition around the discs. *L. plantarum* 299v was included for comparison.

Results

The present work is concerned with investigations into the EPS-producing lactic acid bacteria (LAB) *Lactobacillus* sp. and *Pediococcus* sp. isolated from fermenting cassava and sorghum. The work has involved preliminary investigations of EPS production and determination of its potential prebiotic properties. Isolates were screened for their ability to survive simulated gastric passage at low pH value and in the presence of bile. In addition, a small number of isolates have been screened for production of inhibitors of *Escherichia coli* and *Clostridium perfringens*.

Results have shown that some types of EPS produced by LAB isolated from traditional fermentations have prebiotic properties and that basic probiotic characteristics are present in some isolates. Further work and substantiation is required, but if the preliminary results are confirmed, in situ production of EPS by LAB provides a means of nutritionally enhancing cassava and other fermented food products. At the same time, the putative probiotic properties offer the potential for control of enteropathogens. In addition to enhancement of traditional fermented foods, suitable cultures could be used as the base for development of novel probiotic and prebiotic foods.

Isolation of extracellular polysaccharide-producing lactic acid bacteria. EPS-producing LAB comprised as many as 50% of the total population in cassava and sorghum fermentations (ca. 5×10^7 cfu/g). Quantity of EPS produced varied, but

diversity of bacteria isolated from cassava was low and usually only one type of EPS-producing colony was present. EPS production was more prevalent amongst isolates from sorghum than cassava and diversity was greater, with some colonies producing two distinct types of EPS. EPS-producing LAB included both *Lactobacillus* sp. and *Pediococcus* sp. Lactobacilli were tentatively identified as on the basis of fermentation profiles and *Pediococci* as atypical strains of *P. damnosus*. Identity of two *L. plantarum* isolates was confirmed by sequencing the 16S rRNA gene. Fermentation profiles showed EPS-producing isolates to be capable of utilising a wide range of carbohydrates. These included glucose, fructose, maltose and sucrose, but not starch.

Conditions for production of extracellular polysaccharides. EPS was produced on all substrates tested. There were two patterns of response to different carbohydrates. The first response involved similar levels of EPS production on all substrates. The second response showed slightly greater production on fructose than on glucose and maltose and markedly greater production on sucrose. EPS production appears to mainly occur towards the end of incubation when the cells are assumed to be in the stationary phase. There are indications with some, but not all isolates, that production is greater at 30°C than at 37°C, the optimal temperature for growth.

Differential fermentation of extracellular polysaccharides. EPS was fermented by the cocktail of *Bifidobacterium*, growth being greater than with lactulose. There was also evidence of growth stimulation by EPS in the presence of glucose. *Clostridium perfringens* was unable to grow with lactulose as sole fermentable carbon source, but growth was stimulated by this substrate in the presence of glucose. Neither the non-pathogenic strain of *E. coli* nor the strain of *E. coli* serovar O157: H7 were able to ferment EPS and there was inhibition of serovar O157: H7.

Tolerance of gastric acidity and bile.

Tolerance of gastric acidity and bile varied amongst both EPS- and non-EPS-producing lactic acid from cassava and sorghum fermentations. Two EPS-producing strains of *Lactobacillus* sp. showed higher levels of tolerance to both simulated gastric acidity and bile than the recognised probiotic strain *L. plantarum* 299v.

Production of inhibitors by isolates of lactic acid bacteria. Culture supernatant of some strains of *Lactobacillus* and *Pediococcus* from cassava and sorghum fermentations had an inhibitory effect on growth of *C. perfringens* and, to a lesser extent, both *E. coli* strains tested. The most effective strains, however, were not those producing EPS.

Discussion

EPS-producing strains of *Lactobacillus* sp. and *Pediococcus* sp. are of relatively high prevalence in cassava and sorghum fermentations. No chemical analyses have been made at present to determine structure of the EPS, but produced in equal quantities on different carbohydrates, is probably a heteropolysaccharide, containing more than one type of monosaccharide. The increased quantity of EPS produced by some isolates with sucrose as substrate is probably a homopolysaccharide of the fructan or glucan type, produced in addition to the heteropolysaccharide (personal communication, Dr G. Cote, US Department of Agriculture). Loss of ability to produce EPS when isolates are cultured in liquid medium is consistent with the environmental role of EPS in biofilm formation and would be unlikely to occur in fermentations containing a significant quantity of solid material.

The present studies provide evidence that EPS produced by *Lactobacillus* and *Pediococcus* sp. isolated from cassava and sorghum fermentations can be considered as a candidate prebiotic. This supports previous work demonstrating the prebiotic properties of EPS (Dai Bello *et al.*, 2001; Yamamoto *et al.*, 1999). Fermentation of EPS by

Bifidobacterium was more rapid than that of lactulose and final cell numbers were higher. There was also some stimulation of the *Bifidobacterium* “cocktail” when glucose was also present as a fermentable carbon source.

It is probable that prebiotic efficiency varies between chemically distinct types of EPS. There is considerable diversity within each type and no systematic studies relating structure to prebiotic function has been undertaken. Selection of the most effective type is, therefore, likely to require extensive screening. In the current study, potential prebiotic activity has been defined by differential fermentability in batch cultures. This represents the first stage of identifying candidate prebiotic compounds. Although differential fermentability is a prerequisite for prebiotics, *in vitro* tests with pure strains of bacteria in batch cultures cannot necessarily predict efficacy in the human diet. Demonstration of prebiotic activity to an acceptable level of certainty requires that the number of bifidobacteria be increased in the gut without a corresponding increase in undesirable bacteria. This requires use of a suitable model, such as a two- or three-stage anaerobic fermenter, followed by volunteer feeding trials. The planned next stage of the work involves use of an anaerobic fermenter to extend knowledge of the prebiotic properties of EPS produced by different *Lactobacillus* sp. isolates.

Although prebiotics are incorporated into a range of foods, the compounds involved are added as ingredients to the formulation. Production of prebiotic EPS by bacteria involved in manufacture of fermented foods is a highly attractive concept, since it avoids additional ingredient formulation, procurement and purchase. *In situ* production of EPS in sourdough (rye) bread has been investigated (Korackli *et al.*, 2002; Ticking *et al.*, 2003). In most cases, production of EPS in-situ has been of technological interest in sourdough bread manufacture, but Korackli *et al.* (2002) emphasised the nutritional benefit through prebiotic activity. The evidence of the present work is that nutritional enhancement of cassava and other traditional

fermented food is feasible and probably occurs naturally under some conditions.

The concept of EPS-producing LAB that also has probiotic attributes does not appear to have been considered elsewhere. Probiotic properties are associated with certain strains of a restricted number of species of *Lactobacillus*, although there appears to be wider distribution amongst *Bifidobacterium*. *Lactobacillus plantarum* is amongst species of lactobacilli known to contain probiotic strains, although the organism is not widely used in commercial products. Probiotic properties have also been associated with strains of *Pediococcus* sp.

Commercially used probiotic cultures are all derived from humans or other animals and there is a presumption that only strains from these sources can survive gastric passage and colonise the gastric epithelium. There is no body of evidence, however, for this presumption and some isolates from traditional fermentations were of higher resistance to stomach acidity and bile than the commercially used strain *L. plantarum* 299v. Resistance to stomach acidity and bile are prerequisites for successful use as a probiotic culture, but do not necessarily imply, however, that the organism will have any beneficial effect if ingested. A further recognised attribute of probiotic bacteria is the production of compounds with antimicrobial activity to enteropathogens. Antimicrobial activity to *E. coli* O157:H7 (vt) by *Lactobacillus* sp. and *Pediococcus* sp. isolated from cassava and sorghum has been demonstrated (unpublished work), although the isolates were not significant EPS producers. The number of strains tested was small, however, and there is no known reason why EPS synthesis and production of antimicrobial agents should not occur in the same isolate. It has also been suggested that EPS produced by a strain of *L. delbrueckii* has a beneficial function in stimulating macrophages (Nishimura-Uemura *et al.*, 2003) independent of any effect of the bacterium.

Although antimicrobial activity is usually considered to involve production of specific

inhibitors, such as bacteriocins, fermentation acids, such as lactic and acetic, are also important determinants of safety of fermented foods. A study of cassava fermentation for production of the Ghanaian food, agbelima, for example, concluded that fermentation acids rather than bacteriocins were responsible for the antimicrobial effect of LAB (Mante *et al.*, 2003). Lactic acid is usually the major fermentation acid, but there is increasing recognition of the role of acetic acid in the safety of fermented foods, as well as in setting desirable conditions in the intestine. Examination of fermentation end products of LAB from cassava by gas-liquid chromatography showed high ratios of acetic to lactic acid (unpublished work). This may be due to a metabolic switch following depletion of fermentable carbohydrate levels and the need for an alternative energy source (Calderon *et al.*, 2002). Production of acetic acid is not considered to be a probiotic attribute but high levels are desirable since its activity against enteropathogens is greater than lactic acid.

Although the research described is at a preliminary stage, prebiotic and probiotic properties associated with *Lactobacillus* sp. and other LAB appear to have considerable potential for enhancing the nutritional value of foods based on cassava and other traditional fermented plant products. Recent research has tended to be directed towards the preventative role of probiotic bacteria towards diseases that are prevalent in post-industrial societies, including bowel cancer and immune dysfunction. While these are of considerably less concern in the developing economies of Africa and Asia, modulation of the gut microflora provides a potentially important means of reducing morbidity and mortality due to diarrhoeal diseases as well as providing general health benefits.

A problem with both prebiotics and probiotics is devising a suitable vehicle of delivery (Reid, 2003). In the current situation, there are two options. The first involves setting conditions during the cassava fermentation to ensure maximum EPS yield.

The use of starter cultures is a possibility, but even undefined mixed cultures can be difficult to manage in village-scale operations. EPS-producing lactobacilli are common in natural cassava fermentations and a more effective approach might be to manage the fermentation to increase their prevalence. This may be possible by addition of additional carbohydrate, although better understanding of the dynamics of cassava fermentations may be required to ensure that the most effective lactobacilli are stimulated.

The second option would be the creation of a new functional (probiotic and prebiotic) product using a traditional fermented food as base. The European probiotic product ProvivaÔ is an oat-based, fruit-flavoured drink containing *L. plantarum* 299v. The concept was based on a traditional African fermented product, although strain 299v is a north European isolate from a human source. The use of microorganisms with both probiotic and prebiotic properties would offer considerable advantages with respect both to efficiency as a functional food and simplify production. In addition to health benefits, the development of functional fermented foods would offer new opportunities for local food industries and expand natural product utilisation.

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Requirements and characteristics of potato varieties in the Kenyan potato processing agricultural sub-sector

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Abstract. Crop utilization is an important facet of potato production. Processing potatoes adds value and diversify ways in which they are consumed. In Kenya, the increasing demand for processing potatoes has been spurred among other things by increased tourism, urbanization and changing food habits as well as increased wealth culminating into an expanding processing subsector whose integration in the food production chain is crucial for Kenya's agro-industrial development and long term food security. The objective of the study was to determine the potato quality requirements by processors, and to assess potato processing potential of several varieties and clones obtained from various sites in the country. An informal survey of the potato processing industry in Nairobi was conducted, followed by quality evaluation of potatoes grown in different sites in the country. The potato tubers were evaluated for dry matter content, then processed into chips and crisps and subjected to sensory evaluation using an untrained sensory panel. The commonest potato products on the market were found to be chips (French fries) and crisps. Two varieties, namely, Nyayo and Roslin Tana were commercially most often used in processing into chips while Kerr's Pink and Dutch Robjin were commonly used for crisp production. Newer varieties like Tigoni and Asante were slowly gaining roots in commercial production, as the National Potato Research Centre, Tigoni, develops other varieties. Varieties with high dry matter content were found to be more acceptable when prepared

into chips and crisps, than those with low dry matter content.

Introduction

Potato is an important food and cash crop in Kenya and plays a major role in national food security. The crop contributes in alleviation of poverty and income generation by providing employment opportunities in production, processing and marketing sectors, thereby contributing to the national food security goals. Potato production is undertaken to generate cash for small-scale farmers in major potato growing zones, with the main potato crop being harvested in just one month in two seasons per year. The total potato production is 670,300 tonnes annually (Ng'ang'a *et al.*, 2002) on 93,000 ha (FAOSTAT, 2002). Production is set to expand as it extends to the traditional maize growing zones, with increased production likely to spur increased processing. Marketing of consumption potatoes in Kenya is undeveloped with most potatoes being sold in the fresh form (Guyton, 1994). Processing as an extension of storage life or a mechanism for improving the value of otherwise low quality potatoes (Booth and Shaw, 1981) is on the increase due to a growing processing market and high yield potential.

The most important products in the Kenyan potato processing industry are fresh potato chips (French fries), followed by potato crisps and frozen chips. There has been an explosive growth of fast food restaurants and snack bars selling chips in the urban areas

(Walingo *et al.*, 1998). The processing of potato crisps is also rapidly expanding due to changing life styles and eating habits of urbanized Kenyans. The demand for fried potato chips and crisps is also increasing in Kenya as evidenced by new entries in the processing market. Several large companies are also processing frozen potato chips for sale in leading supermarkets for product diversification. The processing industry requires potatoes with well-defined characteristics including high consumer and processing qualities. Consequently, potatoes destined for processing must meet certain quality requirements to be suitable. Varieties currently in commercial production were developed without considering the processors' demands; hence, the need to look into the quality characteristics of common varieties and clones for their suitability for processing. There are therefore many gaps in the potato processing subsector that needs to be documented as a guideline to processors, producers and researchers for development and production of the desired varieties.

The objective of this paper was to characterize the potato processing market in terms of varieties used, available products and their quality, and to evaluate potato processing qualities of several varieties and advanced clones in order to determine their processing potential and recommend them for specific processed products.

Materials and Methods

Survey of potato processing industry. A formal survey of the potato processing industry was carried out in Nairobi with the aim of characterizing the potato processing market using a questionnaire. The questionnaire focused on varieties used for specific products and problems encountered by processors. Visits were made to randomly selected snackbars and restaurants for chips. A visit to major supermarkets to capture available potato products was also done. Two

major supermarket chains and 10 other small supermarkets across the city were visited. A list of crisps processors was compiled from potato products offered in the supermarkets and formal visits made to the processors to be interviewed. A total of 65 owners or representatives of chips outlets were interviewed across the city. The visits targeted hotels, restaurants and snack bars. Fifteen crisps processors were visited and interviewed. The data collected were analyzed by SPSS statistics package.

Potato quality evaluation. Potato tubers were grown in Kabete (1750 masl), Tigoni (2100masl), Mount Elgon (2300 masl), and Embu (1460 masl). In Kenya, the potato crop is grown mainly in the highlands between 1400 to 2700 masl with an average rainfall of 1000 mm per annum or greater (Rhoades *et al.*, 2002). Most of these potatoes were grown under recommended cultural practices in the national performance trials, on farm evaluation trials and standard international field trials (SIFT) across the country. There were therefore 13 samples from Kabete (5 varieties and 8 clones); 9 samples of 2 varieties and 7 clones from the Tigoni breeding section; 6 samples of 4 varieties and 3 clones from Embu and 4 varieties from Meru. Potato crisps, potato chips and boiled potatoes were prepared from these clones, which were then subjected to sensory evaluations by an untrained panel.

Dry matter content determination. Determination of the dry matter content of raw potatoes was by oven drying at 90°C a 30 g sample of sliced samples from three representative potatoes to constant weight in triplicates.

Processing characteristics: Potato chips (French fries). Representative tubers were washed; hand peeled, chipped manually to sizes of 1mm squares and washed to remove surface starch, then superficially dried using hand towels before frying at 180°C until done.

Potato crisps. Thirty (30) representative tuber samples were used for determination of crisp quality. Potatoes were hand peeled, and a hand operated rotary slicer was used to cut the tubers into 1.3mm slices. The slices were washed in cold tap water to remove surface starch, and dried on a clean hand towel, then put in a wire mesh basket for frying at 180° C using a frifri machine. Fried samples were prepared according to the method of Lulai and Orr (1979) and evaluated on a color score of 1 (very light) to 5 (very dark) using the PC/SFA (1978) color chart. Other quality parameters like texture, flavor, and overall acceptability were evaluated organoleptically.

Boiled potatoes. Representative tubers were boiled in water for 30 minutes, followed by sensory evaluation.

Organoleptic tests. An in-house consumer panel (or pilot consumer panels) comprising of more than 10 panelists selected from personnel of National Potato Research Centre-Tigoni were used to determine the relative acceptability of the boiled potatoes, chips and crisps, and identify any product defects. A 9-point hedonic scale was applied to evaluate sensory attributes of color, flavor, texture and overall acceptability of the chips and crisps. A score of 1 was considered extremely bad while that of 9 was extremely good. Scores of 5 and above were regarded as acceptable.

Results and Discussion

The crisps processing industry in Nairobi uses about 2% of the total potato production in Kenya. The sector has been growing since its inception about 20 years ago, with most of the growth-taking place in the last 10 years. This sector still has potential for growth, as evidenced by the number of enterprises that have sprung up recently. Over 40 local crisps manufacturers were found to be in the market with imported crisps coming from Europe, Israel and South Africa, among others (Walingo, 2002). Local processors are faced

with the challenge of improving the quality of crisps that they produce to be able to effectively compete with the international ones available in the local market. Crisps manufacturers are very specific on the qualities they want in potatoes. There was a marked preference for the potato variety Dutch Robyn, followed by Kerr's pink, which have the desired high dry matter content, round shape and cream flesh color. However, these tubers are often harvested prematurely resulting in undesirable dark crisps.

Potato crisps are packaged mainly in low-density polyethylene that may or may not be printed on. Although polythene is a barrier to moisture and oil seepage, it is not so good a barrier to light or air. A few processors were found to be packaging in the more expensive polypropylene material, which is ideal for crisps as it reduces oxidative reactions that cause breakdown of fats. Within this polyethylene package, evidence of too much oil in the product was clearly visible through the clouding of the package. Draining of excess oil from crisps is necessary before packaging otherwise the crisps become soggy. This can cause rancidity resulting in undesirable odors and flavors, thereby making the crisps unpalatable. To add variety to their products, different flavors including ginger, pepper, cheese, barbeque and different shapes of crisps are produced.

The potato chips snack industry consumes more potatoes than does the crisp sector. However, the amount consumed as chips was difficult to quantify in this study since the establishments did not keep accurate figures on production and some were unwilling to divulge the information. Nairobi City Commission (NCC, 2000) estimates that there are over 800 restaurants and other take-away places selling chips in the city alone. This particular avenue for consumption of potatoes is larger than potato crisps. Although several potato varieties are in use for chips, Roslin Tana and Nyayo, which have dominated the market for decades, are slowly being replaced by other varieties like the newly released Tigoni, Asante and Kimande which have

similar characteristics to Tana and Nyayo but are reported (Lung'aho *et al.*, 2003) to be higher yielding. The general liking is for long shaped tubers.

The findings of this study show that processors are very particular about the quality of the potato varieties they use for processing. This is especially true for crisp manufacturers where only two varieties Kerr's pink and Dutch Robijn are used. For chipping, where tuber quality is not as critical as crisps, various other varieties are used. However, Roslin Tana and Nyayo varieties dominate this market.

The major constraint for processors was the low quality of fresh potatoes, attributed to premature harvesting and mixing of different varieties by farmers. Due to need for quick money or lack of knowledge, farmers harvest potatoes prematurely. In addition, farmers are not given a premium price for good quality potato tubers and therefore have no incentive to keep the tubers until full maturity. This ultimately translates itself in the final quality of the product. The farmers also mix varieties, as the only differentiation for them is either white or red skinned tubers. Tuber maturity is an important quality in fresh potatoes. Good quality potatoes starts with the selection of a good variety grown under good cultural conditions, followed by good handling and storage techniques. Other problems cited by processors included high capital investment for modern equipment; constant power failures and water shortages that result in high losses. The operations are batch type with no level of automation of the processing procedures. The equipments used for processing were also very rudimentary. Most of the processors outside the City Centre buy locally fabricated equipment due to the high cost, which are not so good for controlling temperature during processing. This gives bad quality soggy and dark chips. There is no sorting of tubers and green tubers are often found in the chips. The quality of chips varies across the city with better quality being sold in major hotels and restaurants that target higher income groups than those sold

by snack bars. Such chips are of low undesirable quality although they also cost less. Potatoes are also hand peeled, thus there is a limitation on production capacity per day.

The demand for potato products is likely to increase in view of the increasing population of 4% per year, urbanization and changing food habits. Although most potatoes are eaten fresh in Kenya, like any other developing country, there is an unexploited potential in potato processing. Its use in blended products has yet to be exploited. The frozen fry industry is just but making its debut with a few processors in the market. Most frozen fries are sold in up market supermarkets. Several hotels would prefer to purchase frozen fries as opposed to preparing them from fresh potatoes. These products may offer a more convenient product since preparation of French fries from fresh potatoes is time consuming for fast food restaurants.

Quality evaluation. There were significant differences in the percent dry matter content of the various varieties. Most varieties had acceptable high dry matter content that is desirable for processing. The best clones for processing into chips and crisps were Dutch Robijn, 389746.2, 720118 and 386056.7, which had scores of 1 (one) for both chips and crisps (Table 1). The color of a product is an important sensory attribute, as its appeal to customers will influence their choice to buy the product. In most cases of quality evaluation, emphasis is laid on appearance. The low color scores are indicative of low reducing sugars in the potato tubers. High reducing sugars in fresh tuber results in darkened crisps due to reactions between the reducing sugars and amino acids, making them unacceptable by consumers. A high specific gravity or dry matter content is necessary because it indicates how much water must be evaporated from the potato during the dehydration process. It is actually a measure of the dry matter or "solids" in the potato. High specific gravity potatoes make the best French fries and dehydrated potato products.

Table 1: Dry matter content, chips and crisps colour score from potato tubers obtained from CIP, Kabete.

Variety/clone	Percent dry matter content	Crisps colour score	Chips color score
Asante	21.5	2	2
Dutch Robyjn	22.5	1	1
Torridon	25.7	1	2
720150	26.0	3	2
389746.2	22.0	1	1
720118	25.3	1	1
Sterling	17.5	2	1
380389.1	25.9	2	3
Tigoni	25.7	3	2
3860409	26.2	2	3
387205.5	24.7	2	2
386056.7	24.6	1	1
381390.30	22.0	2	2
Lsd (5%)	0.9807	-	-
CV (%)	15.1	-	-

Based on American Potato and Snack food association color cards on a scale of 1 (light) to 5 (dark).

Physiologically mature tubers have high starch and protein levels and low respiration, water content and sugar levels.

In Table 2, sensory evaluation results for the boiled, chipped and crisped potatoes are presented. There were significant differences for different varieties when processed into the different products. For boiled potatoes, 386040.9, 720150, Dutch Robyjn and Tigoni had highest scores of over six for overall acceptability of the product (Table 2). Other sensory attributes like color, texture and flavor were equally high. Besides color, flavor is one of the most important quality factors of crisps and chips (Pangloli *et al.*, 2002). For the chipped potato, best performers were once again Tigoni, 386056.7 and 381390.30, which had overall acceptability scores of over six. Crisps scores for Dutch Robyjn, Asante, 387205.5, 386040.9 and Torridon were the highest.

KP91301.10 and 720097 had highest dry matter contents with only two varieties having less than 20%. These two are not suitable for processing. Surprisingly, clone 384657.24 scored best for crisps and chips (Table3) yet it had a low dry matter content of only 17.9%. 720097 also, scored, highest for crisps while

Tigoni had a best score of 1 for chips. Clones 384657.24, U5, 72097 and Tigoni scored highly for boiled potatoes (Table 4). The same clones were also best performers for crisp while KP90142.7 and KP91301.10 were the best performers when processed into chips. Except for KP90142.7 and 384651.24 of the material sourced from Mt Elgon site, the rest of the clones had over 20% dry matter content (Table 5). Tigoni and 384651.24 scored best for color of crisps. Table 6 further presents results for sensory evaluation of boiled, chipped and crisped potatoes from Mt. Elgon material. There were significant differences between varieties for all sensory attributes of color texture, flavor and overall acceptability for the three different products of boiled, chipped and crisped potatoes. For boiled potatoes, the best performers were Tigoni KP90142.7 and U5 (Table 6). Best performers for crisps included 384651.24, KP92387.5 and Tigoni; while 920097, KP90142.7 and KP923887.5 were best performers for chips.

K. Pink and Nyayo varieties, which are well adapted in the Embu region, had the highest dry matter contents compared to the newer varieties U5 and KP91301.10 (Table 7). However, both the new varieties scored highly

Table 2: Sensory evaluation results of boiled chips and crisps potatoes from Kabete site.

Variety	Boiled scores			Ovr	Crisps scores			Ovr	Chips scores			Ovr
	Color	Texture	Flavor		Color	Texture	Flavor		Color	Texture	Flavor	
Torridon	6.4	5.7	5.8	5.7	6.4	5.5	5.2	5.8	5.7	5.3	5.9	6.0
	6.2	4.8	5.2	5.3	5.1	5.0	5.3	5.4	6.2	6.3	5.7	5.9
	4.2	4.1	4.1	4.1	4.9	5.0	4.9	5.3	5.3	4.7	4.6	4.9
381390.30	6.7	4.8	4.8	5.0	6.0	6.0	6.2	6.3	5.4	4.9	5.0	5.3
D. Robyn	5.8	6.6	6.7	6.2	4.3	4.3	4.4	5.2	6.3	6.4	6.3	6.7
	5.3	4.7	4.6	4.4	5.4	5.5	5.7	5.8	6.6	5.7	5.7	6.1
	4.7	4.7	4.1	4.6	5.5	6.2	6.1	6.0	5.4	5.9	5.9	5.6
386056.7	4.4	6.6	6.0	5.7	5.5	5.4	5.6	5.9	3.0	4.0	4.4	4.1
720118	5.0	4.7	5.1	4.7	5.3	4.3	5.3	5.4	7.0	6.7	6.1	6.6
3872055	5.3	6.8	6.9	6.6	5.0	4.3	5.1	5.2	4.4	4.4	5.1	5.0
720150	5.2	5.1	5.6	5.4	3.5	4.9	4.2	4.6	5.7	5.9	5.9	5.6
389746.2	6.6	7.2	6.0	6.1	5.9	6.8	6.0	6.5	4.6	4.6	4.9	5.1
Tigoni	6.1	6.6	6.8	6.8	4.5	4.3	4.6	4.5	6.3	5.7	6.4	6.4
386040.9												
Lsd (0.05)	1.398	1.538	1.589	1.537	1.292	1.189	1.341	1.348	1.617	1.314	1.353	1.550
CV (%)	26.9	29.2	30	30	26.9	29.6	30	30	27	22.7	22.9	25.8

1 based on a subjective scale of 1-extremely dislike, to 9-extremely like.

Table 3: Dry matter content, chips and crisp color score for potatoes grown in Tigoni.

Variety	Dry matter content	Potato chips color score	Potato crisps color score
KP91301.10	25.1	3	2
KP92387.5	19.9	3	2
382155.2	22.9	2	2
384651.24	17.9	1	1
KP90142.7	16.8	3	2
Asante	22.6	3	3
720097	24.4	2.5	1
U5	20.4	1	3
Tigoni	22.0	1	3
CV (%)	3.0	-	-
Lsd (0.05)	1.08	-	-

cores are based on PC/SFA scale.

Table 4: Sensory evaluation results for boiled, chipped and crisped products from potatoes grown Tigoni.

Variety	Boiled scores				Crisps scores				Chips scores			
	Color	Texture	Flavour	Overall acceptability	Color	Texture	Flavor	Overall	Color	Texture	Flavor	Overall
Asante	5.4	5.4	5.3	5.4	4.0	4.4	4.7	4.1	4.1	4.9	5.7	5.0
KP92381.5	5.0	5.6	5.4	5.4	4.9	4.8	4.9	4.9	6.0	5.4	5.3	5.4
38465124	7.6	6.4	6.0	7.0	6.7	6.0	5.6	6.3	5.6	5.0	5.6	5.0
KP90142.7	4.7	4.1	5.0	5.0	4.9	5.0	5.1	5.1	7.0	6.1	5.9	5.7
720097	6.3	6.3	5.3	6.0	3.4	4.9	5.1	4.3	6.1	4.6	5.3	5.4
U5	4.9	6.6	6.3	6.6	5.7	6.2	6.4	6.3	6.4	5.9	5.9	5.7
KP91301.10	6.1	6.1	5.6	6.3	6.0	6.0	5.7	6.0	4.0	4.4	4.4	4.9
Tigoni	6.9	5.1	4.9	6.3	6.7	6.8	6.6	6.6	3.6	4.7	5.6	5.4
382155.2	5.3	6.0	5.4	5.4	4.9	5.5	5.9	5.9	3.9	3.3	4.0	4.0
CV (%)	22	26.7	24.7	20.0	31	24	25	23	20.4	27.6	27.1	26.7
Lsd (0.05)	1.362	1.647	1.449	1.283	1.748	1.437	1.537	1.406	1.135	1.461	1.543	1.488

for crisp color, outperforming Asante. Based on their consistently good processing quality, coupled with high field performance across the sites, clones KP91301.10, 920097, KP90142.7 and U5 have been officially given pre-release status as new varieties.

Conclusion and Recommendations

The industry continues to search for potato varieties with better processing quality characteristics to replace the old traditional

varieties like K. Pink and Dutch Robyn for crisps; and Tana, and Nyayo for chips. These varieties have become susceptible to diseases like late blight and viruses hampering their production. The new varieties being developed are not only tolerant to potato diseases but also possess acceptable quality characteristics. A processing potato must have a high specific gravity and low sugar content. High specific gravity is necessary because it indicates how much water must be evaporated from the potato during the

Table 5: Dry matter content, color score for chips and crisps prepared from Mt. Elgon materials.

Variety	Dry matter content	Crisps color score
720097	24.3	2
KP90142.7	18.2	4
Tigoni	26.9	1
KP90301.10	24.0	2
U5	23.4	2
KP92387.5	21.2	3
Asante	20.8	2
384651.24	19.0	1
382155.2	24.2	2
CV (%)	3.5	-
Lsd (5%)	1.372	-

Table 6: Sensory evaluation scores for boiled chipped and crisped potatoes from Mt. Elgon material.

Variety	Boiled scores				Crisps scores						
	Color	Texture	Flavor	Overall	Color	Texture	Flavor	Overall	Color	Texture	Flavor
382155.2	5.0	5.4	5.1	5.4	5.9	5.4	5.0	5.3	5.1	4.4	5.8
KP92387.5	4.4	5.0	4.9	5.0	5.9	6.3	6.0	5.7	6.0	5.5	5.8
384657.24	5.0	4.7	4.7	4.4	7.1	5.6	6.0	6.0	3.8	4.4	3.3
KP90142.7	6.1	4.9	5.1	6.0	5.7	5.4	5.1	5.1	5.7	5.6	5.8
U5	6.3	5.6	5.7	5.7	5.6	5.7	5.6	5.9	5.3	5.0	5.3
Asante	5.3	5.3	4.4	5.0	5.1	5.3	5.4	5.4	5.9	5.0	5.9
KP91301.10	4.6	4.7	4.0	4.1	6.3	5.3	5.1	5.9	4.2	4.8	4.0
720097	5.1	4.1	4.1	4.7	4.7	5.6	5.4	5.4	5.3	5.7	6.0
Tigoni	6.4	6.9	6.1	7.0	7.0	5.9	6.4	6.6	2.9	3.3	3.8
CV	20	22	28	21	18	15	21	17	29	31	29
Lsd	1.156	1.207	1.502	1.191	1.156	1.935	1.267	1.021	1.221	1.313	1.478

Table 7: Dry matter content of Embu materials.

Variety	Dry matter content	Crisps color scale	Chips color score
Kerr's Pink	22.8	1	1
Nyayo	22.7	2	2
Tigoni	19.6	2	1
Asante	19.6	3	2
U5	19.0	1	2
KP91301.10	19.8	1	2
CV	2.4%	-	-
Lsd	0.9005	-	-

dehydration process. High specific gravity potatoes make the best French fries and dehydrated potato products. Lower temperatures or shorter frying time will yield a limp product with poor rigidity; longer frying time or high temperature of oil affects the color of the product (Zak and Holt, 1973).

However, the potato processing industry needs further development. The market is slow in responding to demand. Consumers have shown increased demand for both quality and quantity for processed product, necessitating processors to improve on their products. Local products cannot compete on the international market, as the quality is wanting, both in terms of the actual product and in terms of the packaging. Quality is an essential prerequisite for acceptance of a food product. Consumers select a product according to the external characteristics that are assumed to be indicative of the internal qualities. Kader (1985) indicated that quality factors are the appearance (visual), flavor (taste and odour), texture (feel), nutritive value and safety. Unsuitable varieties, batch type operations, excess oil in product, poor packaging contribute to reduced performance by the potato industry. However, the Kenyan potato industry is currently active in trying to satisfy her customers through linkages between the potato programme and the processors.

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Participatory approach in the development of technologies to control erosion for sustainable cassava production in Thailand

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Abstract. During the first 2-3 months of cassava canopy establishment, part of the soil remains exposed to the direct impact of rainfall, which can cause serious erosion. Complete canopy closure in a cassava crop takes a long time. If farmers do not apply fertilizer to cassava, soil fertility may decline while plant nutrients in the soil may be lost due to erosion when the crop is grown on slopes. Although nutrient extraction and removal by cassava tends to be less compared with many other crops, soil loss due to erosion may be higher because of the crop's slow initial development. Past research has shown that fertilizer application, reduced tillage, contour ridging, mulching, intercropping and the planting of contour hedgerows can greatly reduce erosion. Nevertheless, farmers seldom adopt such soil conservation practices, mainly because the recommended practices are not suitable for the local conditions. They may be too costly or require too much labor, or they may be ineffective. Moreover, farmers are often not aware of the amount of soil lost by erosion. Results of the farmer participatory research (FPR) project in various pilot sites in Thailand indicate that farmers should make their own decisions, and that they are willing to adopt soil conservation practices such as the planting of contour hedgerows of vetiver grass or legumes, if these were shown to be effective in reducing erosion. The use of a farmer participatory approach was very effective as many farmers readily adopted the selected practices and also helped

disseminate these to farmers in neighboring communities. The selected practices would be well-adapted to the local conditions if the farmers made their own decisions and were directly involved in the development of new technologies by planning and implementing the trials together. This is of fundamental importance for enhancing the sustainability of cassava production.

Introduction

Most cassava in Thailand is grown by smallholders in upland areas with low fertility soils and frequent drought conditions. In the northeastern and eastern regions, cassava is often grown on gentle slopes; nevertheless, soil erosion may be quite serious. Since most cassava farmers are poor, they do not apply much fertilizer to cassava and this may lead to a decline in soil fertility which in turn causes low yields.

Past research by Kasetsart University has shown that cultivation of cassava may cause twice as much soil erosion as that of mungbean, and three times as much as that caused by maize, sorghum and peanut (Puttacharoen *et al.*, 1998).

Research on erosion control practices indicate that soil losses due to erosion can be markedly reduced by various agronomic practices combined with simple soil conservation practices. This includes agronomic practices such as minimum or zero tillage, mulching, contour ridging,

intercropping, fertilizer or manure application, and planting at close plant spacing. Soil conservation practices include terracing, hillside ditches and planting contour hedgerows of grasses or legumes. But these latter practices are seldom adopted by farmers because they may not be appropriate for the specific circumstances of the farmers, either from an agronomic or a socio-economic standpoint (Howeler, 2001).

Since 1994, the Nippon Foundation in Tokyo, Japan, has supported the project “Integrated Cassava-based Cropping Systems in Asia: Farming Practices to Enhance Sustainability”. This project has developed and used a farmer participatory research (FPR) and extension (FPE) methodologies to achieve widespread adoption of soil conservation practices.

Materials and Methods

First Phase (1994-1998). The following institutions collaborated in the project.

1. The Department of Agriculture (DOA)
2. The Department of Agricultural Extension (DOAE)
3. The Land Development Department (LDD)
4. Kasetsart University (KU)
5. The Thai Tapioca Development Institute (TTDI)
6. The Centro Internacional de Agricultura Tropical (CIAT)

Activities. During this first phase a Farmer Participatory Research (FPR) methodology was developed and included the following activities:

Selection of suitable pilot sites. These were selected in cassava growing areas, with at least 5% slope, and where farmers and local extension staff were interested in joining the project. In each site, Rapid Rural Appraisals (RRA) were conducted to gather information about the local situation and identify the major problems (Howeler, 2001; Watananonta *et al.*, 2002).

Preparation of field staff. Courses in FPR and RRA methodologies as well as in cassava production technologies were held to train field staff that collaborated in the project.

Demonstration plots. Demonstration plots were established by DOA, KU, LDD or TTDI in areas not too far from the pilot sites. They had a large number of treatments, including application of chemical fertilizers, green manures, closer plant spacing, intercropping with different crops and contour hedgerows of different grasses or legume species. Farmers from new sites visited these demonstration plots and selected treatments to test on their own fields.

Farmers meetings. Farmers in each new site who were interested in participating in the project joined a training course whose objectives were 1) to increase the farmers’ knowledge and understanding of soil conservation in cassava growing areas; and 2) to equip farmers with techniques of conducting trials on their own fields.

FPR trials. After farmers had decided to conduct FPR trials, researchers and extensionists discussed the trials with collaborating farmers and provided the necessary materials. During the crop season, researchers and extensionists visited the farmers several times to discuss and solve their problems. At harvest, collaborating farmers and project staff harvested all the cassava trials together, recorded all data. Data on soil loss from every treatment was also presented to the participating farmers and others interested. The meeting then discussed the results of each trial and selected the best treatments either for adoption or for retesting in next year’s trials (Howeler, 2001; Watananonta *et al.*, 2002).

Scaling-up and adoption. After 2-3 years of conducting FPR trials, farmers usually would be able to select the most suitable treatments to test and then adopt in larger areas of their production fields.

Second Phase (1999-2003). After having developed and tested the farmer participatory research (FPR) methodology in a few sites during the first phase, the project rapidly expanded to more sites during the second phase. These include sites in:

1. Nakhon Ratchasima province in the lower Northeastern region
2. Kalasin province in the Upper Northeastern region
3. Prachinburi province in the Eastern region
4. Chachoengsao province in the Eastern region
5. Chaiyaphum province in the Northeastern region
6. Kamphaengpet province in the lower Northern region
7. Kanchanaburi province in the Western region
8. Roi-Et province in the Upper Northeastern region
9. Ratchaburi province in the Western region
10. Chonburi province in the Eastern region

By 2003, the project had expanded to 33 sites in 21 districts of 11 provinces.

Activities. During the second phase of the project, additional Farmer Participatory Extension (FPE) methodologies were developed with the objective of reaching a large number of farmers. These include:

Cross-site visits. Farmers from new sites visited villages where the project had been conducted before and where new technologies had already been adopted.

Farmer field days at harvest. Local officials and farmers from the village and surrounding communities were invited to evaluate each treatment in the FPR trials, including root yield and the amount of soil sediments eroded from each plot. This way, farmers learned and obtained information to make decisions about technologies suitable for their own conditions. They then discussed and planned for action in the following year.

District level field days. The purpose of these large-scale field days was to disseminate the selected technologies to nearby villages and sub-districts. During the field day, the experienced farmers shared their knowledge with other farmers.

Provincial level field day. At this level, approximately 1,000-1,500 farmers and officials from nearby provinces were invited to attend the field day. Reporters from newspapers and television stations were also invited in order to report the project activities through the wider mass media.

FPR training courses. Initial courses were organized by CIAT to train project staff of DOA, DOAE, LDD and TTDI in FPR methodologies. Additional courses were organized to train local extension workers and key farmers in cassava technologies and farmer participatory approaches. Furthermore, CIAT also supported the training of trainers in advanced courses abroad.

Technology transfer through farmer participatory extension. In order to enhance the transfer of technologies through farmers' participation, a budget was allocated to support 4-6 farmers' meetings annually. The topics included discussions on the problems of project implementation and the possible solutions for both project management and crop production. Local extension workers acted as the coordinators; they sometimes invited outside experts to discuss specific topics according to farmers' needs.

Cassava development villages. Starting in 2000, DOAE further assisted the project implementation by setting up so-called "Cassava Development Villages". DOAE provided the farmers with various materials such as fertilizers, which they had to return to the village—revolving fund after harvest. A specific interest payment was agreed upon by the villagers. Furthermore, the members voted to elect the "Fund Administration Committee" which comprises at least a

president, a vice-president, a treasurer, and a secretary. Members also discussed and decided on the rules and regulations of their community-based self-help group.

Results and Discussion

The data in Table 1 show that most of the hedgerow treatments (T_{12} - T_{18}) as well as contour ridging (T_3) and closer plant spacing (T_8) were very effective in reducing soil loss by erosion. Some of the intercrops (T_9 and T_{11}) and one of the three vetiver grass varieties (T_{16}) competed strongly with nearby cassava, causing a reduced yield. Farmers from several new sites visited these plots. Farmers evaluated the treatments and selected 3-4 treatments that they considered most effective and wanted to try out in FPR erosion control trials on their own fields. Most farmers

selected vetiver grass hedgerows as the most suitable practice, followed by closer spacing, the combined application of fertilizers and chicken manure, contour ridging, and intercropping with pumpkin.

Many results of the FPR trials conducted by farmers in Thailand have already been published (Howeler, 2001; Howeler *et al.*, 2002). Tables 2 and 3 are a few examples of FPR trials conducted by farmers in Kalasin and Chayaphum provinces. They show that both vetiver grass and lemon grass hedgerows were very effective in reducing soil loss by erosion; in some (but not all) cases they also increased yields and net income. Most farmers selected vetiver grass over lemon grass hedgerows because of the former's tolerance to drought and poor soils, and for its ease of planting and maintenance. In addition, farmers observed that contour

Table1: Results of the FPR demonstration plots at TTDI, Huay Bong, Nakhon Ratchasima, Thailand, in 2001/02.

Treatments ¹⁾	Soil loss (t/ha)	Dry cassava yield (t/ha)	Intercrop yield (t/ha)	Starch content (%)	Gross income ²⁾ —————('000 B/ha) ———	Prod. costs (t/ha)	Net income
1. farmers' practice: up/down ridges, no fertilizers	10.50	44.12	-	25.4	53.74	17.59	36.15
2. up/down ridges; 50 kg/rai 15-15-15 fertilizers	37.68	43.51	-	30.9	57.78	20.93	36.85
3. contour ridges; 50 kg/rai 15-15-15 fertilizers	5.86	40.28	-	28.0	51.16	20.06	13.10
4. no ridges; 50 kg/rai 15-15-15 fertilizers	12.06	48.68	-	25.5	59.39	21.51	37.88
5. no ridges; 25 kg/rai 15-15-15 fertilizers	12.70	46.96	-	28.7	60.30	19.42	40.88
6. no ridges; 25 kg/rai fertilizer+125 kg/rai chicken manure	10.83	45.36	-	24.5	54.43	19.85	34.58
7. no ridges; 25 kg/rai fertilizer+1,000 kg/rai compost	13.09	45.63	-	29.0	58.86	20.16	38.70
8. no ridges; closer spacing (0.8 x 0.8 m)	4.52	49.27	-	31.6	66.12	21.98	44.14
9. no ridges; peanut intercrop	11.70	27.00	2.00	26.1	53.26	18.66	34.60
10. no ridges; pumpkin intercrop	5.53	40.41	3.80	23.5	85.68	23.28	62.40
11. no ridges; sweet corn intercrop	16.70	17.80 ³⁾	7.10	25.7	57.29	18.18	39.11
12. no ridges; <i>Leucaena leucocephala</i> hedgerows	5.28	33.80	-	25.4	41.17	18.50	22.67
13. no ridges; sugarcane (for chewing) hedgerows	7.51	44.01	-	23.0	51.49	21.25	30.24
14. no ridges; lemon grass hedgerows	6.51	42.09	0.65	27.2	52.78	20.73	32.05
15. no ridges; <i>Paspalum atratum</i> hedgerows	14.24	39.09	-	23.3	45.97	19.92	26.05
16. no ridges; vetiver (from TTDI) hedgerows	4.69	25.46 ⁴⁾	-	22.0	29.28	16.24	13.04
17. no ridges; vetiver Songkla-3 hedgerows	6.24	46.10	-	26.0	56.70	21.82	34.88
18. no ridges; vetiver from Vietnam hedgerows	8.25	41.68	-	24.6	50.10	20.62	29.48

¹⁾ Variety KU-50; treatments 8-18 were all fertilized with 50/kg rai of 15-15-15 fertilizers, and all treatments except T_8 were planted at 0.8 x 1.25 m spacing; 1 ha = 6.25 rai.

²⁾ Prices: cassava baht 1.31/ kg fresh roots at 30% starch; 0.02 baht reduction for every 1% lower starch content; peanut 10.0/ kg dry pods; pumpkin 10.0/ kg; sweet corn 5.0/ kg; lemon grass 5.0/ kg.

³⁾ Low yield due to strong intercrop competition and poor drainage.

⁴⁾ Low yield due to competition from very vigorous vetiver grass hedgerow.

Table 2: Average results of seven¹⁾ FPR erosion control trials conducted by cassava farmers in Sahatsakhan district, Kalasin, Thailand in 1999/2000.

Treatments ²⁾	Dry soil loss (t/ha)	Yield (t/ha)		Gross income ⁵⁾		Production costs	Net income	
		Cassava	Intercrop	Cassava	Intercrop			
								Total
				——('000 B/ha)——		----('000 B/ha)----		
1. farmer's practice	42.5	21.91	-	14.90	-	14.90	12.73	2.17
2. closer spacing	35.3	26.06	-	17.72	-	17.72	13.87	3.85
3. contour ridging	17.2	24.04	-	16.35	-	16.35	13.78	2.57
4. sweet corn intercrop	9.6	20.28	10,830 ³⁾	13.79	10.83	24.62	15.41	9.21
5. pumpkin intercrop	9.8	31.87	500 ⁴⁾	21.67	1.50	23.17	16.97	6.20
6. lemon grass hedgerows	12.0	25.16	-	17.11	-	17.11	14.38	2.73
7. vetiver grass hedgerows	3.5	18.32	-	12.46	-	12.46	13.01	-0.55

¹⁾ Only four trials for treatment 7, and two for treatment 5

²⁾ No ridging except in T3; all treatments received 312 kg 15-15-15/ha

³⁾ Number of ears/ha

⁴⁾ Number of fruits/ha

⁵⁾ Prices: cassava baht 0.68/kg fresh roots (23% starch)
sweet corn 1.00/ear
pumpkin 3.0/fruit.

Table 3: Average results of two FPR erosion control trials conducted by farmers in Khook Anu village, Thap Sathit district of Chayaphum province, Thailand, in 2001/02.

Treatments	Dry soil loss (t/ha)	Yield (t/ha)		Root starch content (%)	Gross income	Product. costs ²⁾	Net income	Farmers' preference (%)
		Cassava	Intercrop					
1. farmer's practice	14.0	12.61	-	20.3	12,736	12,018	718	0
2. contour plowing	10.2	8.41	-	20.0	8,410	11,471	-3,061	100
3. up/down plowing	31.1	12.34	-	18.3	11,970	11,974	-4	0
4. mungbean intercrop	10.3	8.70	0.306	24.0	15,516	15,392	124	82
5. lemon grass hedgerows	4.5	15.94	-	21.0	16,259	13,550	2,709	0 ³⁾
6. vetiver grass hedgerows	8.0	13.02	-	22.3	13,619	13,083	536	100

¹⁾ Prices: cassava baht 1.20/kg fresh roots at 30% starch
mungbean 20/kg dry grain

²⁾ Cost of cassava production without harvest 10,000/ha
Cost of C+mungbean production 14,000/ha
Extra cost of contour plowing 125/ha
Cost hedgerow planting + maintenance 1,000/ha
Harvest + transport 160/tonne

³⁾ Although lemon grass hedgerows produced the highest net income, farmers do not like this practice because lemon grass does not tolerate drought and it is difficult to sell in large quantities.

Table 4: Location of FPR pilot sites in Thailand in 2002, and the adoption of vetiver grass for erosion control in those sites.

Province	FPR pilot sites			Adoption of erosion control practices			
	District	Subdistrict	Village	No. of farmers	Cassava area withvetiver (ha)	Vetiver(No. of plants)	Vetiver hedge rows (km)
Nakhon Ratchasima	Daan Khun Thot	Baan Kaw	Khut Dook	53	49.4	130,000	15.0
	Thephaarak	Bueng Prue	3 and 6	26	34.2	80,000	11.0
	Soeng Saang	Noon Sombuun	Sapphong Phoot	62	132.5	80,000	20.0
		Sratakhan	Sratakhan	0	4.8	20,000	2.0
Prachinburi	Khonburi	Tabaekbaan	Nong Phak Rai	27	24.0	50,000	5.0
	Naadli	Kaeng Dinso	Aang ThongKhao Khaa{}	34	27.2	60,000	4.5
Kalasin	Mueang	Phuu Pokhamin	Noon SawanKhamplaafaa	61	49.0	85,500	8.6
	Nongkungsri	Nong Bua	Khamsri	67	110.4	111,600	11.2
	Sahatsakhan	Noonburi	Noon Sawaat	63	59.2	86,170	8.6
		Noon Namkiliang	Huay Suea Ten Paa Kluay}	47	40.6	128,330	12.8
Chachoengsao	Naamon	Naamon	Noon Thiang	50	24.0	16,000	1.6
	Don Chaan	Dong Phayung	Noon Kokchik	50	24.0	16,000	1.6
	Huay Phueg	Nikhom	Huay Faa	50	24.0	16,000	1.6
	Sanaam Chaikhet	Thung Phrayaa	Thaa Chiwit Mai	32	10.4	50,000	2.0
	Thaa Takiab	Khlong Takraw	Nong Yai	42	27.2	100,000	5.3
Kamphaengphet	Khanuwaralakburi	Bo Tham	SiyaekTonThoo}	42	27.2	68,000	3.0
Chaiyapoom	Thep Sathit	Naayaang Klak	Khook Anu	42	27.2	68,000	4.0
Kaanchanaburi	Law Khwan	Thung Krabam	Nong Kae	42	27.2	80,000	3.0
Srakaew	Wang Sombuun	Wang Sombuun	Baan Khlong Ruam	75	220.8	90,000	9.0
Total: 8	17	20	24	>865	943.3	1,335,600	129.8

* initiated in 2002.

Table 5: Extent of adoption¹⁾ of various cassava technology components in four pilot sites in Thailand in 2002.

Technology component	Baan Khlong Ruam Sra Kaew		Thaa Chiwit Mai Chachoengsao		Saphong Phoot Nakhon Ratchasima		Huay Suea Ten Kalasin	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Varieties	480	100	469	100	396	100	228	100
Chemical fertilizers	480	100	469	100	364	92	180	79
Vetiver grass hedgerows	139	29	94	20	218	55	89	39
Green manures	72	15	0	0	0	0	114	50
Intercropping	0	0	0	0	0	0	0	0

¹⁾ Estimated by farmers in each site during Participatory Monitoring and Evaluation (PM&E) in Aug 2002.

plowing and ridging, closer plant spacing and adequate fertilization also contributed to reduced erosion and generally increased yields. Intercropping practices are not widely adopted in Thailand because of the high cost of labor. Similar results were obtained in many other sites. Once farmers saw the benefits of the various soil conservation practices, they adopted closer plant spacing, more balanced fertilization and the planting of contour hedgerows of vetiver grass; the latter in turn led to contour plowing and ridging in some areas.

The planting of vetiver grass hedgerows was done either by individual farmers on their own fields or as a community activity. Being one of the first groups to adopt the planting of vetiver grass hedgerows for erosion control on a large scale, farmers in Saphong Phoot village, were visited by many other farmers to learn from them.

In 2001 the Thai government, through DOAE, set up community-based self-help groups, called "Cassava Development Villages", in 11 of the project pilot sites, providing about US\$ 1,000 to each group in the form of fertilizers to initiate a revolving fund. In 2002 this was further expanded to another seven sites and in 2003 to another three sites. Table 4 shows the extent of vetiver grass growing in each of the FPR pilot sites in Thailand in 2002. By the end of 2002 nearly

900 cassava farmers in Thailand had planted about 130 km of vetiver grass hedgerows in 940 ha of cassava fields. It can be assumed that many farmers outside the pilot sites have similarly adopted this technology after hearing about it on the radio or TV, or from extensionists or other farmers through word-of-mouth. The fact that His Majesty the King promotes the use of vetiver grass, and that free planting material is available at LDD stations nation-wide are surely decisive factors favoring the rapid spread of this technology.

In addition to vetiver grass hedgerows, farmers in the FPR pilot sites also tested new varieties, chemical fertilizers and organic manures, green manures and intercropping. Results of a participatory monitoring and evaluation (PM&E) exercise with farmers in four pilot sites in 2002 (Table 5) revealed that in all sites farmers had adopted the growing of new varieties in 100% of their cassava growing area; chemical fertilizers were applied on average in 79-100% of the area, green manures were used in 0-50% of the area, and vetiver grass hedgerows had been planted in 20-55% of the area, depending on the need for soil conservation in each site; no farmers had adopted intercropping. Green manures were adopted mainly in Kalasin province where soils are extremely sandy and almost devoid of organic matter.

Conclusion

The use of a farmer participatory approach for technology development and dissemination was very effective in enhancing the adoption of soil conservation practices. Farmers are generally very interested in testing of new technologies that may produce immediate financial benefits, such as new varieties, organic and inorganic fertilizers, improved weed control etc. A combined package of suitable practices, adapted to local conditions, including soil conservation practices such as the growing of contour hedgerows, is more likely to be adopted than soil conservation practices by themselves. The growing of vetiver grass hedgerows for erosion control is a very suitable technology under the conditions cassava is grown in Thailand. The adoption of more sustainable cassava production practice is likely to improve Thai farmers' living standards.

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Towards identifying the full set of genes involved in postharvest physiological deterioration in cassava

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Abstract. Cassava is the world's sixth most important crop in terms of production and is a vital staple food to over 500 million in the humid tropics. Unfortunately, it suffers from a rapid post-harvest physiological deterioration (PPD) that can render the roots uneatable and unmarketable within 24-72 hours of harvest. Increased urbanization has lengthened the distance and time between farmers' fields and markets and processors, thereby incurring losses, wastage and discounting of poor quality cassava. PPD is a major constraint to the development of cassava for farmers, processors and consumers alike, and the successful application of strategic research is necessary to solve this problem. With a view to fully understanding PPD and to ultimately producing the tools to control this problem, we have identified some of the key genes that play major roles during PPD and mapped these on the genetic map of cassava. Recently, we have embarked on a major programme employing massively parallel methods of gene analysis (cDNA microarrays) to identify the full set of genes involved in PPD. Screening 11,136 cDNA clones from early and late PPD-related libraries using a series of character probes from a range of time points during the time course of deterioration has led to the identification of 114 clones whose expression is increased and 70 clones whose expression is decreased at least two-fold during PPD.

Control of sweetpotato virus disease through Farmer Field Schools approach in Kagera region, Tanzania

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Abstract. Sweetpotato, *Ipomea batatas* (L) is an important crop grown for food and income generation in Tanzania. In Kagera region, it is the most important crop grown by resource poor farmers. The crop has recently become even more important due to the decline in banana production due to pests and diseases. Despite its importance, poor soil fertility, pests and diseases affect its productivity. A survey conducted in 2003 indicated sweetpotato virus disease (SPVD) was a major problem that needed immediate attention. SPVD, a disease caused by a synergistic interaction between the white flyborne Sweetpotato Chlorotic Stunt Virus (SPCSV) and the aphid-borne Sweetpotato Feathery Mottle Virus (SPFMV), is a major threat to sweetpotato production particularly in Bukoba and Muleba districts. Various

control techniques including use of resistant varieties and phytosanitation were considered and implemented through Farmer Field Schools (FFS) approach. In the current study the practical procedures on effective implementation of SPVD control techniques based on FFS approach have been explored. Socio-economic factors affecting adoption and farmers' responses to the FFS approach are indicated. Problems related to FFS in Kagera region are documented and solutions suggested.

Screening of cocoyam (*Xanthosoma Sagittifolium* (L.) Schott) for disease resistance under two contrasting environments

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Abstract. Sixty-six (66) accessions of cocoyam germplasm collection held by the Plant Genetic Resources Center at Bunso, Ghana were screened for their reaction to the common cocoyam diseases under two different soil moisture conditions. One set was grown under rain fed conditions on the upper slope while the second set was grown at the bottom of the slope where the water table was high. The sites were otherwise similar in soil characteristics, such as pH, organic matter content, fertility and texture. The disease incidence and severity were different in the two environments. The percentages of germplasm attacked by various diseases under the upland conditions were: dasheen mosaic virus 18.2%, bacteria leaf necrosis 36.4%, Phytophthora leaf blight

84.9% and cocoyam root rot blight 77.2%. Under the valley conditions, the disease incidence was dasheen mosaic virus (84.9%), bacterial leaf necrosis (62.1%), Phytophthora leaf blight (9.10%), Cladosporium leaf spot (1.5%), Leptosphaerulina leaf spot 1.5% and Concentric leaf spot (51.5%). The devastating attacks of the Cocoyam root rot blight complex and Phytophthora leaf blight diseases under the upland conditions resulted in no economic yield. However, there was reasonable yield of cormels in the lowland conditions where soft rot complex was not detected and Phytophthora leaf blight was mild.

Farmers' perception and varieties acceptability of orange-fleshed sweetpotato in Zanzibar

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Abstract. Ten orange fleshed sweetpotato varieties were introduced in Zanzibar from CIP-Nairobi in November, 2001. The materials received in the form of mini-cuttings were initially maintained and evaluated and bulked at two research stations, Kizimbani and Matangatuani before being sent for on-farm trials. Five elite clones were participatorily selected and taken on-farm for further evaluation and selection. On-farm, (at farmer Field Schools and Farmer Research Groups) the clones were evaluated using a RCB design with each group of farmers as a replicate. Three of the clones (TIB-4, Zapallo and W-151) were highly ranked and selected by farmers and are being recommended for promotion. This paper illustrates farmers perception and the acceptability of these varieties based on their knowledge, agronomic performance and cooking qualities.

Introduction

Sweetpotato has a very important role as a food crop in Zanzibar. It has of late assumed a cash crop status in some areas of the Islands. Though it is ranked fourth after rice, cassava and banana, sweetpotato has a special role as a food security crop. During drought periods, many low income families substitute it for bread and it also features prominently in the food recipes for breaking the fast (futari) during the holly month of Ramadan.

Sweetpotato like other root and tuber crops is a heavy feeder. It does not do well in marginal land therefore farmers in some sweetpotato producing areas of Zanzibar like

Donge Muwanda use urea to improve the fertility of the soil for good production of the crop. Generally, the yield of sweetpotato in Zanzibar is low. Previous studies (COSCA, 1995; KAP Survey, 1994) reported that the average yield of sweetpotato was as low as 5 – 8 t/ha. However, the recently conducted baseline study of cassava and sweetpotato in Zanzibar (Nov, 2001) has revealed that average yield of some selected varieties were as high as 13-15t/ha in farmers' fields (Saleh *et al.*, 2001). Among the important constraints reported to cause the low yield of sweetpotato in Zanzibar were lack of capital for sweetpotato production, poor soils because of continuous cropping on the same piece of land, the use of poor quality vines and growing genetically low producing and disease and pest susceptible varieties (Op cit, 2001). Therefore, there is a need to look for new improved varieties that will be acceptable to farmers. The locally improved varieties SPN/O was introduced in the Islands by the Department of Research in the last few years and it is still the most important variety in the Islands, grown by more than 39% of the farmers (Op cit, 2001).

Sweetpotato in Zanzibar is grown both in the plantation zones where soils are rich and moisture is adequate and at the semi coral rag zone e.g. Bambi juu, Upenja etc. where soils are poor and moisture stress is a common phenomenon. Therefore the availability of drought tolerant varieties in these areas is very important. An experiment was therefore conducted to evaluate, with farmers' participation, the performance of introduced

varieties, and select those that meet farmers' growing conditions and eating qualities.

Materials and Methods

The experiment was conducted in 8 sites for two seasons (2001/2002 and 2002/2003) using seven varieties. Five of them (TIB-4, Salyboro, Zapallo, Tainung 65 and W-151) were introductions from CIP, two were local (SPN/O and Shangazi). All the five CIP varieties are orange-fleshed. They were selected by farmers from among 10 introductions planted on-station. The randomised complete block design (RCBD) was adopted with each site treated as a replication. Each variety was planted on three ridges 10m long and 1m apart. Within rows plants were spaced 0.3m from each other. No fertilizers or herbicides were applied on the plots to simulate farmers' conditions as much as possible. Four farmer field schools (FFS), two Farmer Research Groups (FRG) one prison camp (Magereza) and an individual farmer were involved in the experiment where farmers participated in all activities, from site selection to evaluation of the trial.

The vines were sourced from healthy and young mother stocks. Shoot tip cuttings 25 – 30 cm long were used. At each site soil samples were taken before planting for laboratory analysis. The following data were also taken: plant establishment (%), root yield (kg/plot), number of roots per plot, number of marketable roots per plot, number of non-marketable roots per plot, weight of marketable roots (kg/plot), weight of non-marketable root (kg/plot) and dry matter content (%).

Data were statistically analysed using M stat c computer software. Farmers assessed the varieties in the field using a scale of 1-5 (where 1 = very poor and 5 = very good) for the following characteristics: resistance to diseases, resistance to pests, drought tolerance, maturity, root shape, root size, general root appearance and flesh colour of roots.

The roots were then boiled and farmers assessed each variety for the following characteristics using a scale of 1-3 (where 1 = very good and 3 very poor): Appearance, taste, flavour, starchiness, fibrousness and general acceptability. Data were statistically analysed using the SPSS statistical software.

During the assessment, the varieties were given numbers instead of their actual names to reduce biasness in ranking of popular varieties. For each attribute the majority score was taken for each variety.

Results and Discussion

Soil nutrient content. The results of soil sample analysis are presented in Table 1. In general the soil sample analysis shows that soil fertility status in experimental sites was not a factor that could influence the performance of the sweetpotato varieties.

The Upenja site lies within the semi-coral rag zone (with soils mixed with coral stones). The Fujoni FFS site is situated in the rice valleys of the sandy belt of northern part of Unguja Island. The rest of the zones lie between the belts of plantation area and multi-storey crop patterns.

Farmers' field assessment. The average performance (mean score for all characteristics) of each variety across sites and the overall rank for each is presented in Table 2. In general, SPN/O was the high ranked variety, followed by the orange-fleshed varieties W-151 and Zapallo. Salyboro was the least preferred variety. The local control (Shangazi) was ranked second last (Table 2). This result proves that farmers can evaluate and select their preferred varieties according to their own criteria, skills and experiences.

The mean performance of the varieties for different agronomic traits across 8 sites is presented in Table 3. Significant differences ($P = 0.05$) were observed between varieties for percentage establishment (Table3). Varieties SPN/O and Zapallo had highest percentage establishment of 97.75% and

97.38% respectively, where as variety Salyboro had the lowest (80.94%).

Varieties differed significantly in the number of marketable roots/plot (Table3). SPN/O had the highest number (23) whereas Salyboro and Tainung 65 had the lowest (12). No significant differences were detected between varieties for marketable root weight with a range of 3 – 7 kg/plot (Table3). All the varieties had dry matter contents above 30%.

However, varieties Shangazi (local check), SPN/O, Salyboro and TIB –4 had the highest dry matter contents. The differences between varieties were statistically significant (Table 3).

The mean site performance for the various agronomic characteristic is presented in Table 4. Significant differences existed between sites for number of marketable and non-marketable roots, and dry matter content. No significant

Table 1: Soil properties across eight experiments sites.

Site	Soil type	Sample depth (cm)	pH H ₂ O 1:2.5	Total N ¹ . %	P ² ppm	K ³ meq K ₂ O/100g soil	Na ³ meq/ 100g soil
Mitakawani	Sandy clay loamy	0.30	6.1	0.145	4	0.041	0.111
Junguni	Silt loamy	0.30	7.2	0.100	23*	0.060	0.135
Fujoni	Sandy clay	0.30	6.4	0.084	3	0.064	0.489*
Kinumoshi	Clay loamy	0.30	5.7	0.334*	4	0.136	0.156
Kizimbani	Sandy loamy	0.30	5.6	0.145	6	0.248**	0.052
Upenja	Silt loamy	0.30	7.7	0.282*	45**	0.117	0.058
Matangatuani	Clay loamy	0.30	5.3	0.084	45**	0.120	0.100
Kiuyu	Sandy clay	0.30	6.4	0.066	27*	0.180*	0.207

¹Total nitrogen (N %) was determined by semi micro-Kjeldah method using block digester.

²Available P (P₂O₅) by Spectrometer from Bray and Kurtz 1 extraction.

³Available potassium (K₂O) and Extractable Sodium (Na) were analysed by absorption spectrophotometer (AAS) using NH₄Oac.

Table 2: Average performance of sweetpotato varieties for all characteristics evaluated in the farmers.

Variety	Sites								Mean	Rank
	Mitakawani	Junguni	Fujoni	Prison camp Kinumoshi	Kizimbani	Upenja	Matangatuani	Kiuyu		
TIB-4	3.73	3.34	3.64	3.30	3.09	3.45	3.36	3.54	3.43	4
Salyboro	3.18	2.90	3.18	2.50	2.90	3.09	2.55	3.00	2.91	7
Zapallo	3.73	3.55	3.81	3.36	3.27	3.36	3.63	3.72	3.55	3
Tainung 65	2.54	3.27	3.45	2.63	2.81	3.45	3.36	3.37	3.11	5
W – 151	3.90	3.82	3.63	3.27	3.63	3.73	3.81	3.72	3.69	2
SPN/O	4.00	3.72	3.81	4.00	3.73	4.00	3.81	3.73	3.85	1
Shangazi (control)	2.7	3.18	3.09	3.00	3.18	3.00	3.27	3.27	2.96	6

Field across eight sites.

N.B. Subjective ranking is 1 – 5.

Where 1 = very bad; 2 = bad; 3 = moderate; 4 = good; 5 = very good.

differences were detected between sites for marketable root weight.

Plant establishment was lowest at Upenja FRG (85%). This was not surprising because this site is dominated by poor soils (coral rag) and moisture stress is a common phenomenon. At this site, farmers rated variety Zapallo the best. Zapallo also proved the best performer under water logged conditions at Donge Muwanda (this site was

later abandoned due to floods). All the other varieties perished. Furthermore, Zapallo was highly preferred by farmers because its narrow leaves resemble those of a popular local variety whose leaves are used as a vegetable (mtoriro).

The average performance of the varieties for cooking qualities across the sites is shown in Table 5. In general five varieties (TIB-4, W-151, Zapallo and SPN/O and Tainung 65) were

Table 3: Mean performance (per plot) of seven sweetpotato varieties across eight sites evaluated by two seasons (2001/02, 2002/03).

Variety /clone	Establishment (%)	Plants with storage roots	No. of marketable roots	No. of non-marketable roots	Weight of marketable roots (kg)	Weight of non-marketable roots (kg)	Dry matter content (%)
TIB – 4	89.50	8.88	15.50	8.38	4.48 (14.9)	0.62 (2.0)	34.88
Salyboro	80.94	7.88	12.38	4.63	3.33 (11.0)	0.52 (1.7)	35.51
Zapallo	97.38	8.63	13.75	3.87	4.32 (14.4)	0.35 (1.2)	30.13
Tainung 65	75.88	7.25	12.50	6.63	7.08 (23.5)	0.46 (1.5)	30.14
W.151	92.05	8.38	16.13	6.25	4.65 (15.5)	0.61 (2.0)	31.14
SPN/O	97.75	8.70	23.38	8.75	6.72 (22.3)	0.85 (2.8)	36.16
Shangazi	92.75	8.47	22.00	5.57	5.52 (18.3)	0.55 (1.85)	36.51
Mean	89.40	8.30	16.52	6.29	5.16	0.56	33.49
LSD (0.05)	10.39	1.21	3.21	NS	NS	NS	4.88
CV (%)	8.88	14.45	42.63	69.42	96.93	77.7	11.14

Figures in brackets represent ton/ha, NS = Not statistically significant.

Table 4: Mean site performance for several agronomic characteristics of seven sweetpotato varieties evaluated for two seasons (2001/02, 2002/03).

Sites	Establishment (%)	No. of plant with storage roots /plot	No. of marketable roots/plot	No. of non-marketable roots	Weight of marketable roots (kg/ plot) roots/ plot	Weight of non-marketable roots (kg/ plot) roots (kg/ plot)	Dry matter content (%)
Mitaka. FFS	86.93	7.00	13.14	4.71	3.06	0.50	36.99
Upinja FRG	84.94	9.14	10.71	5.29	3.80	0.30	31.11
Kiuyu FRG	96.14	8.86	16.43	4.57	8.62	0.14	31.90
Fujoni FFS	91.71	9.14	15.00	5.85	5.30	0.95	33.97
Kizimbani	90.29	6.71	16.43	10.29	4.44	0.76	29.67
Kinumoshi	92.58	9.57	17.00	9.00	5.23	1.06	33.57
Junguni FFS	86.29	8.86	18.50	5.28	3.97	0.35	31.66
Matangatuani	86.82	8.43	24.80	5.57	6.78	0.24	34.09
Mean	89.46	8.46	16.50	6.32	5.15	0.53	32.57
LSD (0.05)	9.38	1.45	8.33	5.04	NS	0.52	4.412

Table 5: Mean scores of seven sweetpotato varieties for seven cooking characteristics evaluated across eight sites for two seasons (2001/02, 2002/03).

Site	Average score (1-3) for combined attributes per variety.						
	Varieties						
	TIB-4	Salyboro	Zapallo	Tainung	W-151	SPN/O	Shangazi
Mitakawani	1.00	1.50	1.17	1.50	1.00	1.70	2.00
Upinja	1.00	1.50	1.33	1.17	1.17	1.33	1.33
Kiuyu	1.00	2.00	1.50	1.00	1.00	1.67	2.16
Fujoni	1.67	1.50	1.33	1.67	1.60	1.00	1.67
Kizimbani	1.00	1.66	1.67	1.33	1.17	1.33	1.50
Kinumoshi	1.17	1.67	1.00	1.67	1.17	1.00	1.67
Junguni	1.00	1.83	1.00	1.50	1.00	1.17	1.83
Mat/tuani	1.17	1.67	1.17	1.33	1.00	1.17	1.33
Overall mean	1.12	1.66	1.27	1.39	1.13	1.29	1.68
Overall rank	1	6	3	5	2	4	7

N.B The subjective ranking score is 1-3 where as 1 =good, 2 moderate and 3 = bad.

Table 6: Mean scores of six sweetpotato cooking characteristics for seven varieties evaluated across eight sites for two seasons (2000/01, 2001/02).

Sites	Attribute (Score 1-3)							Rank
	Appearance	Taste	Flavour	Starch	Fibrousness	General acceptability	Mean	
Mitakawani	1.57	1.14	1.42	1.42	1.14	1.28	1.33	5
Upinja FFS	1.28	1.00	1.57	1.51	1.00	1.14	1.26	1
Kiuyu	1.57	1.42	1.42	1.28	1.14	1.57	1.40	8
Fujoni FFS	1.42	1.28	1.14	1.42	1.14	1.28	1.28	3
Kizimbani	1.20	1.28	1.42	1.42	1.00	1.28	1.30	4
Kinumoshi	1.42	1.00	1.57	1.57	1.14	1.42	1.33	5
Junguni	1.57	1.42	1.28	1.28	1.14	1.28	1.33	5
Mat/tuani	1.28	1.28	1.42	1.42	1.00	1.42	1.26	1
Mean	1.44	1.22	1.38	1.45	1.08	1.33		
Rank	5	2	4	6	1	3		

Ranking score 1-3 (1=good, 2=moderate, 3= bad).

rated “good” across the sites. Two of them (Salyboro and the local check-Shangazi) were rated “moderate” (Table 5).

All the cooking qualities were rated good for all the varieties across sites. It is also noteworthy that these varieties were not fibrous and tasted sweet (Table 6). Farmers in

Zanzibar prefer non-fibrous sweet varieties (Saleh and Mohammed, 2001).

Conclusion and Recommendations

From this experiment, it was observed that farmers’ participation in selection of the

varieties is very important in enhancing adoption of new technologies (varieties). Farmers Field School and Farmers Groups were vital in this work.

All the seven varieties possessed had attributes desirable to farmers. All the seven varieties will therefore be recommended to farmers. Farmers at each agro-ecology will select the varieties to adopt.

More on-farm testing of these varieties should be encouraged. In addition, measures should be put in place for multiplying and distributing quality planting materials for the selected materials.

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Determinants of farmers' adoption of improved cassava and sweetpotato varieties in Sierra Leone

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Abstract. The capacity of most African countries to produce enough food for their people is declining in the face of a rapidly increasing population and civil conflicts leading to dependence on food imports and food aid. Adoption and sustenance of farm technologies that can help enhance food production remain a major challenge for research and development agencies in many African countries. Over the years, the Institute of Agricultural Research (IAR) has made substantial efforts in improving the productivity of small-scale farmers in Sierra Leone through the development of improved technologies. This paper is based on a survey of 280 farmers in six operational zones of IAR in Sierra Leone. The results show that improved cassava and sweetpotato varieties developed by the institute have been adopted not only by farmers who have collaborated with IAR in developing and testing these

technologies, but by other farmers too. The results however indicate that among other constraints, the adoption of the improved varieties is inhibited considerably by limited finance and lack of high yielding and diseasefree planting materials acceptable by both the producers and consumers. The findings further suggest that farmers' religion, marital status, sex, income sources outside agriculture and collaboration in on-farm research are important in influencing adoption and should therefore be taken into consideration by research and development agencies in the promotion of root and tubers crops in Sierra Leone.

Production of instant cassava noodles

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Abstract. To increase the utilization of composite flours from cassava, soybean and wheat, this paper report findings on the chemical and sensory qualities of instant noodles from cassava, soybean and wheat. Flour from cassava, wheat and soybean were used in different formulations (90:7.5:2.5; 80:15:5; 70:27.5:7.5, 60:30:10; 100:0:0; and 0:100:0 to cassava–wheat–soybean) to produce instant noodles. Chemical and sensory properties of the instant cassavawheat-soybean samples were analyzed. The result obtained from the proximate analysis showed that increase in percentage of cassava in the noodle sample increased the carbohydrate, ash and fibre content,

respectively. There were significant differences ($P < 0.05$) in the sensory attributes (color, aroma, appearance, flavor, taste and texture) of the instant cassava-wheatsoybean samples. Statistically ($p < 0.05$), noodles produced from 100% wheat flour were the most acceptable by the panelists, closely followed by those made from 60% cassava, 30% wheat, 10% soybean; and, 70% cassava, 27.5% wheat, 7.5% soybean, respectively.

Influence of the initial moisture contents on the functional and sensory qualities of dried *fufu*

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Abstract. The influence of different initial moisture content on the functional and sensory qualities of dried *fufu* was investigated. The properties used were pH, total titratable acidity, water absorption index, water binding capacity, dispersibility, amylose, and pasting as well as sensory qualities. The influence of different initial moisture content on acidity, water binding capacity, dispersibility and amylose content were not significant, except for water binding capacity and water absorption index, which ranged from 127.8% to 130.8% and 109% to 162.6% respectively. All the samples attained peak viscosity at almost the same time and formed paste at the same temperature (74.8°C). The peak viscosity and final viscosity ranged between 669.8 and 705.8 RVU and 467.2 and 518.9 RVU, respectively. The breakdown

viscosity and setback viscosity ranged from 276.5 RVU – 290.5 RVU and 87.9 RVU – 91.0 RVU, respectively. There was significant differences ($P < 0.05$) in the panelist rating of all the sensory qualities (colour, odour, texture and overall acceptability) of the *fufu* dough prepared from *fufu* flour with different moisture content. *Fufu* flours made from wet mass with initial moisture content of 50% results in a more attractive cooked *fufu* dough and was rated highest in all the sensory qualities (especially texture).

Crop response of swamp taro to organic sources of nitrogen in lower gangetic plains

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Abstract. Swamp taro (*Colocasia esculenta* L. Schott) is a wet land minor edible aroid grown in flooded or swampy situation. The crop is grown on a small scale particularly in irrigated lowlands or low-lying ditches of eastern India. The crop being a long duration (8 to 10 months) depletes major plant nutrients particularly nitrogen from the soil. Therefore, the field experiments were under taken to study the nitrogen requirement through organic and inorganic sources in alluvial soil of Lower Gangetic Plains (23.5°N latitude and 89°E longitude and 9.75m above mean sea level) of West Bengal, India during 2001 and 2002. The treatments comprised of different organic and inorganic combinations of 25, 50, 75 % of normal dose of nitrogen (200 kg ha⁻¹) taking mustard cake, neem cake, poultry manure as organic sources and urea as an inorganic source. The stolons (edible part) that initiated from basal sucker corms were harvested periodically at 15-day intervals after attaining suitable marketable length (80 to 100 cm) throughout the stolon bearing period (April to October). Observations on stolon production and yield attributes revealed that inorganic nitrogen source significantly increased stolon production (27.3 tha⁻¹) by 38 to 67 % whereas organic nitrogen sources like mustard cake, neem cake, poultry manure increased the yield (19.7 to 24.3 tha⁻¹) by 21 to 49 % over non fertilized crop (16.3 tha⁻¹). Increased proportions (75 %) of inorganic N source along with organic N-source (25 %) recorded the maximum stolon production (25.2 tha⁻¹). Interaction effect of N-source and its combination was found significant and 50% mustard cake + 50% urea recorded the highest stolon yield of 27.6 t ha⁻¹. The stolon length, stolon number basal girth and plant height were significantly influence by the N-source and its combinations.

Effect of cassava (*Manihot esculenta*) root meal supplemented with Nile Perch (*Lates niloticus*) fish waste on the rumen environment

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Abstract. The supplementary effect of cassava (*Manihot esculenta*) root meal (CRM) and Nile Perch (*Lates niloticus*) fish waste (FW) on the rumen environment was compared to that hominy meal (HM) and cotton seed cake (CSC). The feed's degradability characteristics and chemical contents, rumen pH and rumen ammonia nitrogen (NH₃-N) levels in cows fed on four ration combinations (HM + CSC, CRM +CSC; HM + FW and CRM +FW) denoted as T₁, T₂, T₃, T₄, respectively) were determined. Results showed that DM degradability at 48h for CRM was higher (P<0.05) than that of HM (920 vs 835 g/kg). HM had higher (P<0.05) CP content than CRM (946 vs 837 g/kg) respectively. Both DM and CP contents of CSC were higher (P< 0.05) than those of FW (739 and 887 vs 367 and 598 g/kg) respectively. The degradability of DM for the TR₁ and TR₂ rations was higher (P< 0.05) than that of TR₃ and TR₄ (801 and

799 vs 727 and 616 g/kg DM respectively. TR₂ had higher (P< 0.05) rates of DM degradability than the rest of the rations. The ruminal pH and NH₃-N values differed (P< 0.05) between treatments. Treatments containing FW (TR₃ and TR₄) had higher (P< 0.05) NH₃-N than those containing CSC (TR₁ and TR₂) (284.7 and 203.7 vs 135.8, and 183.9 mg/l). It is concluded that CRM when fed in combination with FW gave higher DMD values and provided a better fermentation environment than HM and CSC. It is further concluded that CRM and FW could be good substitutes for HM and CSC as sources of energy and nitrogen for dairy cattle and other ruminant animals.

Participatory evaluation and improvement of cassava and sweetpotato processing machines for the Eastern zone of Tanzania

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Abstract. Cassava and sweetpotatoes are important crops for improving livelihood of Tanzanians but have not been fully exploited, partly due to limited use of appropriate technologies to produce value added products. Most of the common cassava processing machines available in the market, but not popular in Tanzania, were chippers and graters of the International Institute of Tropical Agriculture (IITA) design. Popularization of such machines in Tanzania requires thorough participatory testing with stakeholders. Testing of the manual chipper and engine-powered grater in Muheza and Kibaha districts for peeled cassava resulted in unsatisfactory results. These were throughput of 11-18 kg/h and 270 kg/h for the manual chipper and the engine-powered grater, respectively. Despite the low throughput they were very difficult to operate. The engine-powered chipper resulted in throughput of 752 kg/h but lack of safety belt cover discredited it. Improvement on these machines mainly included use of pillow block bearings and increased stability for the manual chippers, provision of safety belt cover for the engine-powered chipper, and change of feed hopper design for the engine-powered chipper and grater. The exit chute design for the engine-powered grater was also modified. The modified machines were ergonomically satisfactory and their throughput increased by more than 100% with high acceptance levels. These machines are

capable of processing cassava and sweetpotatoes into various value added products. From the capital cost point of view farmers can easily acquire manual chippers. Engine-powered machines are relatively expensive and can be acquired by a group of farmers or a single entrepreneur.

Introduction

Cassava (*Manihot esculenta*) and sweetpotato (*Ipomoea batatas*) roots are very important for the livelihood of Tanzanians. Cassava is more productive per unit of land and labour than even the high yielding cereals (Moran, 1976) and the highest producer of carbohydrate of all cereals and tubers (Vries, 1978). It is also increasingly becoming important in the fresh, boiled, roasted and fried forms (Ndunguru *et al.*, 1994; Nweke, 1994). The remarkable importance of sweetpotato tubers is the easiness to convert its carbohydrate into starch at the household enterprise level (Marter and Timmins, 1992) and suitability for consumption during hard labour due to its high sugar content. With the roots/tubers being the main edible part, these crops are highly perishable once harvested. Cassava deteriorates 2-3 days after harvesting mainly because the roots are reproductively inactive (Emekoma, 1994), hence the rapid setting in of physiological changes and subsequent rot and decay (Booth, 1976; FAO, 1986). Losses of up to 50% in monetary value

have been reported (Ndunguru *et al.*, 1999). Inefficient harvesting and post-harvest handling (Boccas, 1987) can contribute to more quantitative losses.

Sweetpotato deteriorates at relatively lower rate with shelf life of almost 4 weeks (Anon, 1991). Sometimes, farmers use delayed harvesting tactics, with cassava being able to survive up to 2 years (Moran, 1976) and harvest the crops when required but this form of storage leads to poor quality and unnecessary holding of land. As the conventional storage methods are not feasible for these crops, the practical is processing into value added products. This enhances rural income generation (Wheatley *et al.*, 1996) and food security since simple and low cost technologies can be used. Introducing cassava processing in areas where the crop was only consumed in the fresh forms was successful in Latin America (Best *et al.*, 1991; Henry, 1992).

In Tanzania, traditional processing of cassava entails fermentation processes employed for the bitter varieties and non-fermentation processes employed for the sweet cassava varieties to obtain dry products for flour production. In these methods peeling, size reduction through multiple slicing by hand held knife, and sun drying are involved. In addition to processing into flour, sweet cassava varieties are grated for making local dishes using a rasped metal sheet (Silayo *et al.*, 2001). These methods are very rudimentary, leading to low appeal, short shelf lives, and in isolated areas high cyanogenic residues among others (Msabaha and Rweyangira, 1990). Improved and appropriate processing and packaging techniques will eliminate these problems (Nweke *et al.*, 1998).

Improved processing requires use of tools and techniques that are reliable, efficient, labour saving, safe, simple, and cost effective. The manual vertical reciprocating slicing machine developed at Sokoine University of Agriculture (Silayo *et al.*, 1999) was hard to operate and inefficient, requiring a lot of improvement. The noble way has been to adapt cassava chipping/slicing and grating

machines of the International Institute of Tropical Agriculture (IITA) design, previously not known in Tanzania. An approach to involve farmers right from the field trials of these machines was used. The main objective of this study was therefore to establish suitability of some IITA chipping and grating machines for adaptability in Tanzania based on farmers own perceptions and evaluations.

Materials and Methods

Acquisition and description

Manual slicers. A manually operated slicing machine (Figure 1) of the IITA design equipped with a two-blade slicing disc was obtained from Uganda. This was made to be fixed on a table but due to seemingly added costs of fixing it permanently on a table and thereby rendering it immovable, a decision was made to manufacture a similar one (Figure 2) locally with provision for fixing on four light wooden stands. This would allow personnel to work while standing and quick manoeuvre. For each of the machine, chipping disc for interchangeability of slicing and chipping activities was also manufactured. The manufacturing work was done in collaboration



Figure 1: Manually operated slicing machine.



Figure 2: Manually operated slicing machine with wooden legs.

with Reliable Motor Works workshop in Dar es Salaam. The main functioning features of the manual chippers/slicers were the frame, the chipping/slicing disc, and a small feed hopper with a feed chute that progressively increases from 4 to 10 cm and two-stage feeding angles, the first one at about 30° and the second one at about 60° from the horizontal plane to the chipping/slicing disc. The chipping/slicing disc was mounted vertically with disc shaft running through sleeve bearings. The chipping disc featured eight symmetrical clusters of 5 mm diameter holes, each cluster bearing 14 holes in double rows running in convex mode from the centre to the periphery. Disc support stiffeners separated clusters where the disc was firmly bolted.

Engine powered chipper (Figure 3). This was also acquired from Uganda and featured a feed hopper that was wide (45 cm x 30 cm) and slightly inclined (8°) to the horizontal, a chipping disc mounted on the frame with pillow block bearings, a system of pulleys, a driving belt, and a 5 HP petrol engine (Briggs and Stratton type). Configuration of the chipping disc was the same as for manual chipper described above. Power transmission

ratio was 1 to 4, and distance between pulley centres was about 50 cm.

Engine powered grater (Figure 4). This was also of the IITA design manufactured in collaboration with Reliable Motor works in Dar es Salaam. The main features were a two-side concave hopper with 30 cm x 30 cm feed opening, a horizontally mounted rasped drum



Figure 3: Engine powered chipper.

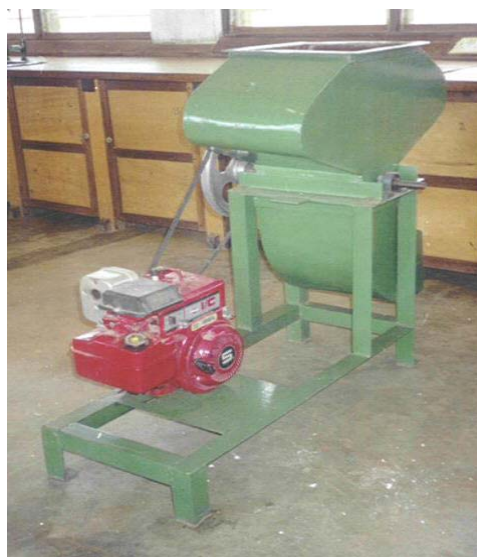


Figure 4: Engine powered grater.

at about 30 cm from the opening with the gripping surface 3 cm below the drum top surface, an exit chute oriented about 30° from the horizontal, a system of pulleys, and a driving belt for transferring power from a 5.5 hP petrol engine. The rasped surface resembled that of the traditional cassava-rasping sheet (Figure 5) used for small-scale grating (Silayo *et al.*, 2001). The drum length and diameter were about 29 cm and 18 cm, respectively. Power transmission ratio was 1 to 4 and distance between pulley centres was about 60 cm. The gap between the drum and the gripping surface was about 4 mm. Modification of chipping and grating machines

Chippers. Modifications to the equipment above (Figures 2, 3 and 4) were made based on recommendations from the participating farmers, extension agents, researchers, and local equipment manufacturers after testing the equipment. Following this, several modifications were made and participatory testing exercises conducted in order to improve performance and acceptability. Made in collaboration with Intermech Engineering Co. Ltd of Morogoro, the concluded modifications were use of pillow block bearings (Figures 6 and 7) for the manual chippers and fixing of the wooden stands in a trapezoidal mode for the manual chipper on wooden stands (Figure 7).

A more improved version of chipper called pedestal-type chipper was also manufactured (Figure 8). This took the same features of the

modified manual chippers but with increased hopper size (39 cm x 35 cm) and a welded metal stand, making the overall height of the machine 95 cm. Another modification was a re-design of the engine-powered chipper to make it dual purpose so that it could be operated with a 3.5-5.5 HP engine or without



Figure 6: Table mounted manual chipper with pillow block bearings.



Figure 7: Wooden legged manual chipper with pillow block bearings.



Figure 5: The traditional cassava-rasping sheet.



Figure 8: Pedestal-type chipper.



Figure 9: Engine-powered pedestal-type chipper.

the need to imitate the pedestal-type chipper and provision of belt safety cover (Figure 9).

The grater. Modifications to the grater mainly included provision of a hopper box (42 cm x 40 cm) with a base inclined at about 35° extended close to the top surface of the rotating drum in order to improve gripping to the working surface and minimize splattering, and a vertical straight rectangular (40 cm x 22 cm) exit chute (Figure 10). The drum was made

of hard wood, with length and diameter of 39 cm and 15 cm, respectively. The drum was fixed with stainless steel pins instead of rasped aluminium or galvanized sheet. The pins were fitted in about 12 rows along the length of the drum at intervals of about 2 mm from pin to pin and protruding 2 mm above the drum surface. The drum was run by a 5.5 HP engine (Briggs and Stratton type), with power transmission ratio of 1 to 2 and 30 cm distance between the transmission pulleys.

Equipment testing. Due to the high cost of making a working table for fixing cassava slicing/chipping machine, the manual chipper/slicer that was meant to be operated while fixed on a table was operated while held firmly on the ground (Figure 1), parallel with the same design that was improvised with wooden legs (Figure 2). At both the inception and the modification stages chipping and grating machines were tested by 40 participating farmers about half of them women, in collaboration with researchers and extension agents in Kibaha and Muheza districts and researchers at Sokoine University of Agriculture. The experiments were done on local cassava varieties and prior to chipping and grating the roots were peeled



Figure 10: Engine powered grater.

and washed to avoid introducing soil particles that could damage the moving parts of the machines. The parameters evaluated were weight processed and processing time. These were converted to throughput (kg/h). Other parameters included percent losses measured as the amount that passed through the machine without being processed, acceptability, and physical attributes of the machines during processing. The mean throughputs and losses were compared using analysis of variance and separated using Duncan's Multiple Range Test ($P=0.05$) (Steel and Torrie, 1980).

Results and Discussion

Performance of the newly introduced machines

Chippers/slicers. Operating the manual slicer/chipper with the two-blade slicing disc

was very difficult, and some farmers, especially women failed to crank the disc continuously. This led to rejection of these machines when fitted with the two-blade slicing disc by almost all farmers who participated in the testing. With the slicing disc replaced with the chipping disc the machines (chippers) performed slightly better but the throughput values were still very low (Table 1). Working with the manual chipper fitted with wooden legs resulted in higher output compared with working with the same machine on the ground while bending. However, use of these machines was labour intensive, as they require two operators, one for feeding and another for cranking the chipping disc. Manual chipping resulted in high losses (19-20%). These were the portions that were just broken and some passing without being processed. This was caused by high concentration of fibers at the end of the roots, which resulted in the last bits of

Table 1: Performance and acceptability of chipping and grating machines before modifications.

Type of machine	Factory price (T shs)	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	40,000	11.4±1.3 ^d	20±2.01 ^b	26.9
Manual chipper fixed on wooden stands	45,000	18±1.9 ^c	19±1.80 ^b	26.7
Engine-powered chipper	-	752±2.0 ^a	7±1.20 ^c	58.4
Engine-powered grater	790,000	270±6.32 ^b	29±2.49 ^a	2.5

Values bearing different superscripts in a column are significantly different ($P<0.05$).

Table 2: Performance and acceptability of chipping and grating machines after modification.

Type of machine	Factory price (T shs)	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	60,000	81.6±0.19 ^e	18.03±1.11 ^c	49
Manual chipper fixed on wooden stands	70,000	99.3±0.30 ^d	17.2±0.93 ^c	54
Pedestal type chipper	120,000	136±0.14 ^c	14.8±1.30 ^a	93
Engine-powered chipper	780,000(5.5 HP engine)	768±1.78 ^a	5.68±0.51 ^b	89
Engine-powered grater	780,000(5.5 HP engine)	507.7±2.52 ^b	Nil	74

Values bearing different superscripts in a column are significantly different ($P<0.05$).

cassava not being processed, suggesting the removal of the end portions before chipping. The thin roots also ended up being broken or passed without being processed. In addition, manual chippers were still difficult to operate as observed by 50% and 29 % of the respondents for the chipper operated while on the ground and that fixed on wooden stands, respectively. This was mainly due to the use of sleeve bearings on the disc shaft. The former was more difficult to operate because one had to bend while operating it, making it more ergonomically unfit. The engine-powered chipper had the highest score, including throughput, which was more than thirty times the manual chippers. Nevertheless, this machine showed some drawbacks, including allowing passage of unprocessed chunks. This was due to the same reasons as for the manual chippers. Another drawback was exposure of the driving belt, which was a safety hazard. Acceptability of the manual chippers was low, (27%) while that of the engine-powered one was relatively high (58.4%). The results show an increase of acceptability with increasing throughput and decreasing losses (Table 1), implying that these factors influence adoption rates. Some respondents (25%), however, suggested the need to experience working with all the types of chipping machines, with an implication that the observed performance could have been higher.

The engine-powered grater. In comparison with the local rasping sheet that can only produce about 4 kg/h of grates (Silayo *et al.*, 2001) the performance shown by the engine-powered grater (270 kg/h) was relatively high (Table 1). However, the machine faced almost absolute rejection by farmers, advocating improvement. This was due to a number of problems including choking of the exit chute due to low angle of exit, low gripping by the drum due to poor hopper design, and splattering of cassava chunks due to poor hopper design and high speed of the drum, which were caused by design and

manufacturing errors. To assist gripping, one had to press cassava against the drum using a wooden paddle fixed on a long stick, which was cumbersome.

Performance after modifications

Chippers/slicers. Mean throughput of the improved manual chippers (Table 2) increased by more than five times while that of the improved engine-powered grater increased by about two times compared with the unimproved ones (Table 1). The increase in throughput corresponded to decrease in losses and increased acceptability despite the relatively higher purchasing cost. Improved throughput was due to provision of pillow-block bearings on the disc shaft of the manual chippers that resulted in smooth rotation compared with use of sleeves before modification. Same as before modifications the manual chipper on wooden stands demonstrated higher performance (99.3 kg/h) than when operated on the ground (81.6 kg/h). The pedestal-type chipper (Figure 8) resulted in throughput that was 16% higher and losses that were 13% lower than for the modified manual chipper on wooden stands. This was mainly due to the use of pillow-block bearing and increased feed hopper size, although stability due to increased weight by the supporting metallic structure could also have contributed. This suggests that throughput from the manual chipper on wooden stands could be improved further if the hopper size was increased. Use of the engine-powered chipper resulted in about eight times and six times as much throughput compared with the modified manual chipper on wooden stands and the pedestal-type chipper, respectively. The respective losses were lower by about 67% and 62%, showing superior performance of the engine-powered chipper. The results also indicate a positive correlation between increase in acceptability with increasing throughput and decreasing losses, making the pedestal-type chipper the best preferred amongst the manual chippers,

irrespective of the relatively high cost. At the purchasing cost of about 780,000 Tanzanian shillings, the engine-powered chipper resulted in a very high throughput but its acceptability decreased slightly from that of the pedestal-type chipper. This was due to higher cost compared with pedestal-type chipper. This implies that acceptability of chipping machines is a compromise between performance and capital cost. Consequently, this requires careful consideration by technology developers, manufacturers, and extension agents for adoption and sustainability. Preliminary testing of chipping machines with sweetpotatoes also produced good chips. These chips could be used for frying or drying where there is need.

The modified engine-powered grater.

Throughput of the modified grater (Table 2) was almost twice as much that of the unmodified one (Table 1) and no losses were experienced. Due to the absence of other versions of graters to compare with apart from the crude rasped sheet acceptability of the improved grater was high. The observed throughput would increase if operators experienced working with this machine for a longer time. The paste produced was generally fine except a few large fibrous particles that could be removed manually before further use for products such as starch and *kibabu* (*kebab*) (Silayo *et al.*, 2003).

Conclusions

The participating stakeholders successfully tested the manual chipping machine and the engine-powered chipper received from Uganda. Performance of the manual chipper was unsatisfactory while that of the engine-powered chipper was satisfactory pending provision of safety belt cover. Performance of the IITA design of grater made in Tanzania was also unsatisfactory. Due to involvement of farmers in the testing successful

modifications of these machines were achieved and performance improved. However, the manual chippers need to be made with enlarged feed hopper to increase throughput. Due to its superiority over other chippers, the pedestal-type chipper needs popularization for wider use to produce chips. The slicing disc for interchanging with the chipping disc need to be improved and the performance of the subsequent processes on chips and slices be evaluated and compared. Intensive work on use of these machines for diversifying use of sweetpotatoes is also required. Due to economic constraints it is recommended that the engine-powered machines (chipper and grater) be owned by farmers' groups or by a single entrepreneur for providing service to the community. Fuel consumption and energy expenditure on these machines under field conditions need to be evaluated. Innovations to produce improved manually operated graters for individual smallholder farmers seem inevitable. In order to attract more customers to acquire the proven modified machines a thorough cost-benefit analysis is required in all transects of societies involved in cassava and sweetpotato farming in Tanzania.

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Preface to the 13th ISTRC Proceedings

Tropical root and tuber crops have been the subject of a series of international symposia held in various countries for the last couple of decades. It all begun from the efforts of research workers who wanted to share information arising from their research on tropical root crops. Thus, they conducted a series of meetings to discuss tropical root crops. The benefits of such gatherings were so apparent that it was decided to establish an organization to spearhead such meetings. The society that came to be established was a professional scientific association called International Society for Tropical Root Crops (ISTRC). The Society, established in 1970, has since been organizing a triennial event, the ISTRC Symposium in different countries. The event has provided a valuable forum where scientists from all tropical and subtropical countries meet to review the current status of root and tuber crops research. The focus of the ISTRC and its symposia is mainly on cassava, sweet potato and yams. Aroids and other tubers form a small part of the presentations.

This proceedings of the 13th triennial symposium of the ISTRC held at the Arusha International Conference Centre in Tanzania from 10-14 November, 2003 reports the meeting of about 200 root and tuber crops scientists, and development workers from 23 countries in four continents (Africa, Asia, Europe and America). The symposium was jointly organized by the Tanzania Commission for Science and Technology (COSTECH), Ministry of Agriculture and Food Security (MAFS) and the International Society for Tropical Root Crops (ISTRC). Hon. Dr. Ali Muhamed Shein, the Vice President of the United Republic of Tanzania officiated the opening ceremony while Hon. Zabein Mhita, MP, Deputy Minister for Science Technology and Higher Education closed the symposium.

The main objective was to bring together people from various research backgrounds to share knowledge, research results and experiences with regard to tropical root and tuber crops. The specific objectives were: to identify knowledge gaps and priority areas for further research and development and the roles for different stakeholders; to synthesize research findings for informed decision making and appropriate policy interventions; and to develop strategies on the way-forward in strengthening public – private collaborative activities aimed at improving food and nutrition security, and reducing poverty.

In this 13th Triennial Symposium of the ISTRC a total of 176 research papers were presented. It also featured a poster and technologies' exhibition. They included research in the areas of Plant Breeding and Biotechnology, Agronomy, Plant Protection, Post- Harvest and Marketing, Social Economics and those representing experiences from the Vitamin A for Africa (VITAA) activities. Three Keynote addresses were made. In cases where full papers were received, these have been published under their appropriated categories. Where full papers were not received, abstracts have been published at the end of each section. This 13th Triennial ISTRC Symposium Proceedings is published in 2 volumes. Volume 1 is composed of Plant Breeding and Biotechnology, Agronomy and Plant Protection papers. Volume 2 is made up of Post-Harvest and Marketing, Socio-economics, Technology Transfer and VITAA papers.

COSTECH and MAFS are highly acknowledged for successfully organizing the symposium with minimum resources from ISTRC Secretariat. The 12 sub committees and their teams that worked day and night to ensure the success of this symposium deserve commendation. India accepted to host the 14th triennial symposium of the ISTRC in November 2006.

The new Executive Council was elected for the 2004-2006 period. Some former council members were retained but in new positions. The Council is made up of:

President: Prof. A. Westby
Vice-President (Fund Raising): Dr. R. Kapinga
Secretary Treasurer: Dr. C. Bonsi
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Correlation study on population dynamics of ginger soft rot inciting pathogens under different organic amendments, disease incidence and its survival in Darjeeling hill soils

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Abstract. Ginger soft rot complex disease incited by *Pythium spp.*, *Fusarium spp.* and *Ralstonia solanacearam* survived extended periods in naturally infested ginger rhizosphere soil. In pieces of organic matter or dead roots application of Farm Yard Manure (FYM) along with different locally available organics like neem cake, FYM, leaves extract of *Scima walllichii*, garlic extract and mustard oil cake were investigated the effect on the population dynamics of the pathogens. The inoculum densities were decreased markedly due to amendments of the different organics in the plots in comparison to the check plots. Analysis of variance implicated that propagule density of two fungal pathogens viz. *Fusarium spp.* and *Pythium spp.*, in the ginger rhizosphere soil steadily declined with the application of the organic extracts. The correlation matrix study on the propagule density of the pathogens at the different growth stages revealed that decreasing inoculum density of two fungal pathogens was highly significant with decreasing disease. The application of FYM with mustard cake and neem cake showed significant reduction of *Fusarium spp.* and *Pythium spp.* and population of *Ralstonia solanacearam*, respectively and increased the fresh rhizome yield. The microscopic observation also revealed that the survival of fungal pathogens in the plant debris presented several epidemiological considerations.

***In-vitro* plant regeneration via somatic embryogenesis and multiple shoot production in an elite ginger cultivar**

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Abstract. Direct production of somatic embryos from the meristematic tissue of elite ginger cultivar ‘Garubathan’ have been developed and more frequently plant regeneration with multiple shoots has been obtained through secondary embryogenesis. Different ex-plants were incubated in the Murashige – Skoog (MS) media with varied concentration of 2,4-D and BAP and sucrose for direct induction of embryogenic calli and promotion of multiple shoots. The rapid initiation and development of somatic embryos were noticed from the meristematic tissue ex-plants cultured in the MS medium with 2% sucrose, 10% coconut milk pulsed with 2,4-D 1mg/l and BAP 1mg/l. The frequency of secondary embryogenic cells production was also higher when cultured in the medium. Response of embryogenic calli regeneration and multiple shoot production varied depending on the strength of the MS medium and concentration of BAP and a consistent production of multiple shoots was achieved on ¾ strength MS medium with BAP 5mg/l. Scanning electron microscopy and histological examination of embryogenic calli revealed a clear organised globular and bipolar structures, which hold great promise for germplasm conservation and genetic manipulation of ginger.

Morphological and biochemical characteristics of promising Indian sweetpotato cultivars and identification of virus infecting sweetpotato in India

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Abstract. Phylogenetic relationship of twenty-two promising Indian sweetpotato (*Ipomoea batatas*) cultivars was determined through morphological and yield parameters. Mahalanobis Multivariate D₂ analysis was performed with a view of tracing relationship among the cultivars. Based on sixteen significant characters, four distinct clusters (Gr. I- 11, Gr.II- 9, Gr.III- 1 and Gr.IV- 1) were obtained. This grouping was concordant with the other characters used in cladistic analysis. Association of morphological characters with yield and yield attributing factors were also studied to work out the direct or indirect effect of different characters on yield. The biochemical parameters of the tubers viz. carbohydrate, crude and soluble protein, ascorbic acid, dry matter content were determined. Significant variation of the proximate nutritional composition was observed in the tested cultivars. The mineral profile viz. Fe, Mn, Cu and Zn in the tubers

was different among the cultivars.

Occurrence of the viruses among the cultivars was also determined visually and by NCMELISA.

Twelve different types of virus

symptoms were found in the test cultivars.

NCM-ELISA gave positive results for some viruses. The present studies have provided a detailed insight among the twenty-two sweetpotato cultivars, which would contribute to the crop improvement programme.

Heap fermentation of cassava (*Manihot Esculenta* Crantz) in Nampula province, Mozambique

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Abstract. Cassava (*Manihot esculenta* Crantz), a tropical root crop, is an essential part of the diet of the inhabitants of Nampula Province in Northern Mozambique. The root is mostly consumed after processing by heap fermentation and sun-drying. The study investigated the microbial and biochemical changes occurring during traditional heap fermentations in three households. The cassava was fermented over a period of 4 days. Temperature values at which extensive mould growth was observed ranged from 26 to 29°C. Lactic acid bacteria increased from 10^4 to 10^6 cfu/g during the fermentation. Isolates were identified as *Leuconostoc pseudomesenteroides*, *Leuconostoc mesenteroides*, *Enterococcus faecium* and *Weissella*

cibaria. Moulds identified were *Neurospora sitophila* and *Rhizopus stolonifer*. The pH values of the cassavas decreased from 6.1 ± 0.01 to 5.6 ± 0.6 during heap fermentation. Average total cyanogenic levels in nonfermented cassava flour was 158 mg HCN/kg, while in fermented cassava flour, a value of 17 g HCN/kg was recorded. Protein concentration in the cassava flour slightly increased from 1.3 % to 1.8 % w/w dry matter during fermentation.

Application of consumer preference and sensory evaluation to sweetpotato research in East Africa

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Abstract. Sweetpotato is a major staple food and income source in several regions of Tanzania and other countries of sub-Saharan Africa. Research, funded by DFID Crop Post Harvest Programme, has sought to expand the potential for introducing improved cultivars, extend the storability of sweetpotato at the farm and prolong the shelf-life during marketing. Consumer preference and sensory evaluation can play an important role in these research projects and has been applied at the rural village level. This paper explores the sensory and consumer approaches developed and applied and outlines some of the statistical tools used to analyse and interpret the results. For example, in cultivar selection, sensory panels and consumer preference studies have been used to investigate regional and seasonal variations in the preference and sensory characteristics of sweetpotato cultivars. Models were developed to relate sensory attributes used by a trained panel to consumer preference. In other studies, simple techniques were developed for use by farmers so that sweetpotato could be evaluated under field conditions. Implications and approaches for future research are discussed.

Selection of sweetpotato with high protein and/or low trypsin inhibitor activity

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Abstract. Low content of protein and the presence of anti-nutritional factor ‘trypsin inhibitor’ diminish the nutritional value of sweetpotato (*Ipomoea batatas* L.) as animal feed. Efforts have been made to develop sweetpotato with high content of protein and/ or low activity of trypsin inhibitor (TIA). Crude protein content and TIA of more than 800 breeding lines of sweetpotato were measured during 5 seasons from 1998 to 2002. Seven lines were selected as low TIA (14 to 120 TUI/mg DW) and 15 lines as high protein (26.1 to 46.6 mg/g DW), when compared to a standard variety ‘Shiroyutaka’ (TIA: 148 TUI/ mg DW, protein content: 17.4 mg/g DW). There was a strong positive correlation between protein content and TIA ($r=0.856^{**}$). However, Q94128-1 (TIA: 6 TUI/mg DW, protein content: 26.8 mg/g DW) and KNF94225-13 (TIA: 59 TUI/mg DW, protein content: 32.0 mg/g DW) had high contents of protein but low TIA. Activity staining of trypsin inhibitor in the proteins extracted from these two lines on polyacrylamide gel revealed lack or less activity of trypsin inhibitor.

Acceptability studies of orange-fleshed sweetpotato varieties in Uganda

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Abstract. Use of orange-fleshed sweetpotatoes (OFSP) as a food-based approach has been suggested as an alternative option to combat vitamin A deficiency (VAD) in Uganda. The OFSP have high β -carotene and are seen as a cheaper and complementary source of vitamin A for the rural poor families who are the most vulnerable to VAD in Uganda. The opportunity is that about 90% of the rural poor households in Uganda use sweetpotato as a staple or co-staple. However OFSP are not known to most of the communities. In this study, we used farmer managed trials as a way of screening and introducing OFSP varieties to communities in Uganda. The study has shown that Ejumula and SPK 004 are the most accepted OFSP varieties in Uganda. Good yields and appealing flesh colour were the reasons put forward for their acceptance by both adults and children.

Introduction

In Uganda about 28% of children and 60% women are reported to be vitamin A deficient (VAD) (UDHS, 2002). The deficiency exposes children to common illnesses, impairs their growth, development, vision as well as immune systems. In severe cases it results in blindness and death (Ruel, 2001), with between 15000 and 60000 death cases reported annually. In women, VAD increases the risk of death during pregnancy, results in low birth weight in children and may increase

chances of HIV/AIDS infection. In Uganda campaigns to combat VAD include among others administration of vitamin A capsules and vitamin A rich natural and fortified foods. Although these have a positive impact, their sustainability is poor especially for the rural poor. Food-based approaches are seen as a viable option for the rural poor. In Uganda, vitamin A rich crops that can be adopted by the rural populations include carrots, fruits and green vegetables. The potential is even bigger with the orange fleshed vitamin A rich sweetpotatoes. Unlike other crops, sweetpotatoes grow and are consumed almost across the country. About 90% of the rural poor households eat sweetpotato as a staple or co-staple, leading to a per capita consumption of 119 kgs. Unfortunately, the cultivation of OFSP has not been widely adopted. Studies were therefore conducted to introduce and evaluate the acceptability of the OFSP varieties among the rural poor communities in Uganda.

Materials and Methods

Seven sweetpotato varieties, namely Ejumula, SPK 004, Kala, Sowola 6, Sudan, 4-4, and Naspot 5 were evaluated between 2001 and 2003 in seven districts representing three major agro ecological zones (Tables 1 and 2). SPK 004 is an introduction from Kenya while the rest are local Ugandan varieties. The seven districts were Kabale, Ntungamo, Mpigi, Luwero, Busia and Soroti. Of the seven

Table 1: Morphological characteristics of orange-fleshed sweetpotato varieties tested in different agro-ecologies of Uganda.

Variety	Flesh colour	Skin colour	Maturity	DM category
Ejumula	Deep orange	Cream	4	High
SPK 004	Orange	Red	4	High
Kala	Light Orange	Cream	4	High
Sowola 6	Orange	Cream	5	High
Sudan	Orange	Cream	6-7	High
4-4	Light Orange	Cream	5	High
Nasplot 5	Light Orange	Red	5	High

Table 2: Characteristics of different agro-ecologies of sweetpotato in Uganda.

Region	Locations	Rainfall (mm)	Topography	Vegetation
Central	Mpigi Luwero	1200 - 1500	Low land	Tropical rain forest
Eastern	Busia Soroti	500 - 1200	Low land	Dry savanna grassland
South Western	Ntungamo Kabale	1500 - 1750	Highlands	Montane grass land

varieties only Ejumula, SPK 004 and Kala were evaluated in all the sites. The evaluation was done with farmer research groups. Access to these groups was made through grass root organizations - AFRICARE in Kabale, VEDCO in Luwero, and SOCADIDO in Soroti. Individual volunteer farmers adopted a mother baby trial system where each group established a group trial and other trials. The trials were planted and managed by farmers. They also made observations throughout the trials' life cycle and also collected data. The plot sizes and methods of planting varied with locations. Five months after planting, the trials were harvested and evaluated for performance. Various attributes were assessed using a subjective score of 1-5, where 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good. Field performance attributes used for varietal assessment were foliage coverage, resistance to diseases and pests, drought tolerance, maturity period, root yield, shape and size of roots, root skin

appearance, root flesh appearance and general crop appreciation. Crop yield was also recorded. In addition, sample roots of each of the harvested varieties were peeled, cooked and served separately to children between 7 and 10 years and adult men and women. Cooked roots were assessed for appearance, taste, flavour, starchiness, fibrousnesses and general acceptability using a similar subjective scoring used in the field. Pair wise rankings of varieties were also done for both field performance and consumer acceptance (Chirimi *et al.*, 2000; Munga *et al.*, 2000, Wanjekeche *et al.*, 2000). Data analysis was carried out using the Statistical Package for Social Sciences (SPSS).

Results and Discussions

Yields of orange-fleshed sweetpotato varieties in Uganda. Sweetpotato storage root yields across sites are presented in Table 3. The yields varied with varieties and across

Table 3: Indicative yield* performance of OFSP varieties in different agro ecologies of Uganda between 2001 and 2003.

Location	Root yields (t/ha) of orange-fleshed sweetpotato varieties						
	Ejumula	SPK 004	Kala	Sowola 6	Sudan	4-4	Naspot 5
Luwero	5.2	3.9	5.0	-	-	-	-
Mpigi	10.0	7.3	10.6	4.4	-	7.1	2.5
Kabale	12.7	8.0	9.6	7.3	-	11.0	1.7
Busia	9.5	8.3	12.3	5.3	6.7	7.5	-
Soroti	8.9	8.0	8.7	5.2	6.7	1.2	-
Ntungamo	25.1	12.5	10.3	9.8	16.3	-	-
Mean	12.1	8.0	9.4	6.4	9.9	6.6	2.1

*Yields are averaged over years.

locations. Overall variety means across locations showed that Ejumula was the highest yielding variety (12.1 t/ha). Apart from Mpigi and Busia, Ejumula yielded higher than the other varieties in the rest of the locations. This suggests that it may be a yield stable variety. This was followed by Sudan, Kala, and SPK 004. Although Naspot 5 yield estimates are not across all study sites, it gave the least average yields (2.1 t/ha), confirming reports from farmers and field extension officers about the poor yields of this variety.

A comparison of on-farm and on-station yields for the 3 best yielding varieties (Table 4) reveals great yielding potential of these varieties under improved agronomic practices. For example Ejumula can yielded up to 38 t/ha, which is well beyond the national average (Mubiru, 2000). The observed yield variation is probably due differences in the yielding potentials of the different varieties and

differences in the climatic conditions across the locations (Mubiru, 2000).

Field evaluations of OFSP varieties by farmers. Evaluation data for OFSP varieties is presented for 2 districts, Luweero and Soroti. In Luwero, farmers ranked Ejumula the best variety at field level (Table 5). Detailed data presented in the table seem to suggest that farmers liked Ejumula for its flesh root appearance, yield, as well as good root characteristics like shape and size. However, it is important to note farmers' dissatisfaction with Ejumula over its poor foliage coverage, disease and drought tolerance. Ejumula is known to be susceptible to virus infections (Mwanga *et al.*, 2004). This together with poor tolerance to drought affects the foliage cover of the variety, which in turn affects planting material availability at the on-set of the season. Good seed multiplication schemes that aim at maintaining clean planting material are recommended as a solution if Ejumula is to be widely adopted by farmers in Uganda. Field assessment results from Soroti (Table 6) were similar to Luweero results. Similarly, results obtained from the rest of the districts revealed a similar trend.

SPK 004 was ranked the second in Luwero despite its low scores on general variety appreciation than Kala and the local checks. This is probably due to better foliage coverage, pest and disease resistance and

Table 4: On farm and on station yield performance comparison in Uganda.

Variety	Yield (t/ha) ranges	
	Farmers' fields	On-station
Ejumula	5-17	12-38
SPK 004	5-16	14-35
Kala	3-13	10-33

Table 5: Farmers assessing* orange-fleshed sweetpotato varieties in Luwero district, Uganda 2001/2002.

Variety	Foliage cover	Disease resistance	Pest resistance	Drought tolerance	Early maturity	Root yields	Root shape	Root size	Skin appearance	Flesh appearance	General acceptance	Rank
Ejumula	2.5	2.7	3.2	2.7	3.8	3.8	3.9	3.7	3.7	4.1	4.2	1
SPK 004	3.6	3.9	4.0	3.7	3.3	2.9	3.1	2.9	3.5	3.5	3.5	2
Kala	3.1	3.5	3.7	3.3	3.5	3.6	3.6	3.3	3.4	3.2	3.8	3
Local checks	3.9	4.0	4.1	3.9	3.5	3.5	3.6	3.4	3.7	3.6	3.9	5
Mean	3.3	3.5	3.8	3.4	3.4	3.5	3.6	3.3	3.6	3.6	3.9	-
CV %	18.6	16.9	10.8	15.6	5.8	11.2	9.3	10.0	4.2	10.4	7.5	-

*Subjective ranking: 1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good; N = 103.

Table 6: Field assessment* of orange-fleshed sweetpotato by farmers in Soroti district, Uganda 2002/2003.

Variety	Foliage cover	Disease resistance	Pest resistance	Drought tolerance	Early maturity	Root yields	Root shape	Root size	Skin appearance	Flesh appearance	General acceptance	Rank
Ejumula	3.6	3.8	3.6	4.0	4.2	4.4	4.3	4.3	4.3	4.5	4.5	1
SPK 004	4.3	4.9	4.0	4.1	3.7	3.8	3.8	4.1	3.8	3.9	4.0	2
Kala	3.3	3.7	4.0	3.9	4.1	4.1	4.1	3.9	4.1	4.1	4.1	3
Sowola 6	3.9	4.0	3.9	4.0	3.4	3.1	3.2	3.2	3.6	3.7	3.5	5
Sudan	3.8	3.9	3.7	4.0	3.6	3.7	3.2	3.3	3.6	3.7	3.9	4
4-4	3.6	3.9	4.2	3.3	2.3	2.0	2.1	2.1	2.0	2.7	2.2	6
Mean	3.8	4.0	3.9	3.9	3.6	3.5	3.5	3.5	3.6	3.8	3.7	-
CV %	9.0	10.9	5.6	7.5	19.2	24.6	22.9	23.0	22.6	15.8	21.7	-

* 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good; N = 112.

flesh root appearance. During assessments farmers asserted that SPK 004 had more and clean planting material and envisaged no planting material scarcity for the variety compared to Ejumula. Farmers in Soroti, like in Luwero were dissatisfied with Ejumula's foliage coverage, disease and pest resistance. However, unlike in Luwero farmers in Soroti found Ejumula tolerant to prolonged dry weather. This is probably due to the fact that the variety originates from this area and is probably adapted to the local conditions (Mwanga *et al.*, 2004). Similarly, SPK 004 was the second best preferred variety in Soroti. Apart from dissatisfaction with yields, farmers seem to like it for its good foliage coverage, root shape and size. The variety, 4-4 performed poorest and was the least preferred in Soroti for field performance. This was primarily because of its poor yields, which was associated with small and poor shaped roots. The variety was also late maturing.

Although the local varieties were generally the least preferred, they were scored above moderate for foliage coverage, pest and disease resistance as well as tolerance to prolonged dry spells. Local check varieties consisted of varieties that have over a period been grown by farmers and were already liked for a number of attributes including adaptability.

Consumer acceptability studies of orange-fleshed sweetpotato. Unlike for field assessment of the OFSP varieties where only adults were involved, both adults and children participated in consumer acceptability tests of the varieties. Results from two study sites, Luwero (Table 7) and Soroti (Table 8) are presented.

In Luwero, both adults and children generally preferred the cooked roots of Ejumula to the rest of the varieties. Whereas adults felt that Ejumula is good for all the

Table 7: Assessment* of cooked OFSP in Luwero district, Uganda, during 2001/2002.

Varieties	Consumer acceptability attributes assessed by farmers						Over all Rank
	Appearance	Taste	Flavor	Starchiness	Fibrousness	General acceptance	
Adults (N = 119)							
Ejumula	4.5	4.2	3.9	4.1	4.1	4.4	1
SPK 004	3.8	3.8	3.7	3.8	3.7	4.2	2
Kala	3.4	3.7	3.3	3.9	3.3	4.0	4
Local checks	3.1	3.5	3.4	3.8	3.5	3.9	3
Means	3.7	3.8	3.6	3.9	3.7	4.1	-
CV	16.4	7.7	7.6	3.6	9.2	5.4	-
Children (N = 105)							
Ejumula	5.0	4.8	4.7	4.8	4.2	4.8	1
SPK 004	4.2	4.2	4.0	4.6	3.3	4.2	2
Kala	4.0	3.9	3.7	4.7	3.4	3.9	3
Local checks	3.9	4.1	3.6	4.6	3.5	3.8	4
Means	4.3	4.3	4.0	4.7	3.6	4.2	-
CV	11.6	9.0	12.4	2.0	11.3	11.8	-

*1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good.

Table 8: Post harvest assessment of orange-fleshed sweetpotato by adults and children in Soroti, Uganda 2002/2003.

Varieties	Consumer acceptability attributes assessed by farmers						Over all Rank
	Appearance	Taste	Flavor	Starchiness	Fibrousness	General acceptance	
Adults (N = 115)							
Ejumula	4.5	4.4	4.1	3.7	3.9	4.3	1
SPK 004	4.0	4.3	3.9	3.9	4.1	4.3	2
Kala	4.1	4.0	3.9	3.9	4.0	4.2	4
Sowola 6	3.8	3.9	3.6	3.6	4.0	3.8	5
Sudan	4.2	4.4	4.2	4.1	4.0	4.3	3
4-4	3.3	3.5	3.4	3.5	3.4	2.8	6
Means	4.0	4.1	3.9	3.8	3.9	4.0	-
CV %	10.2	8.6	7.7	5.9	6.4	15.1	-
Children (N = 49)							
Ejumula	4.5	4.1	3.9	4.0	4.3	4.3	1
SPK 004	3.8	3.9	4.0	4.0	4.2	3.7	4
Kala	4.1	4.1	4.4	4.4	4.3	3.9	2
Sowola 6	3.7	4.3	4.1	3.8	4.2	3.8	5
Sudan	3.8	4.1	3.9	3.9	4.1	4.0	3
4-4	3.4	3.1	2.9	2.9	3.3	2.9	6
Means	3.9	3.9	3.9	3.8	4.1	3.8	-
CV %	9.7	11.0	13.0	13.2	9.3	12.4	-

Subjective ranking: 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good.

attributes except flavour, children felt it was good in all attributes. Children were emphatic on the cooked root appearance, which they all felt was very good for them. The dissatisfaction expressed by adults on the flavour of Ejumula, is probably due to the squash-like-flavour characteristic of most OFSP varieties. For adults, SPK 004 cooked roots were the second most preferred variety, followed by Kala and lastly the local checks. In Soroti, Ejumula was the best variety for both adults and children. However, the two age groups differed on the second preferred variety. While adults chose SPK 004 as the second best variety, children preferred Kala.

Farmers' observations on the overall acceptability of orange-fleshed sweetpotato. This section presents sentimental comments

made by farmers at different times during the evaluation process of the OFSP varieties. In Soroti for example, a farmer observed, "It is very sweet and we do not even need sugar while taking our tea". Sweetpotato is commonly used for breakfast in many Ugandan households. In Kabale, a male farmer referred to the appearance of the varieties as that of "egg yolk". There is a general perception that eggs are a nutritious food among Ugandan communities and therefore this resemblance implies that OFSP are nutritious. In Mpigi, a farmer likened the appearance of cooked roots of OFSP as of cooked bananas. In Central Uganda people have a historical liking for bananas and therefore any association of the OFSP with bananas suggests acceptance among the people in this region. A lot more testimonies

have been heard from mothers. “My children enjoy eating orange types of sweetpotato” many mothers were heard commenting during the evaluations.

Conclusions

It is clearly evident from the findings of the study that OFSP varieties are acceptable to the rural based communities in Uganda. Ejumula and SPK 004 are the most accepted varieties in Uganda for both field and consumer performance. At field level they produced average good yields and were also liked for their starchiness by adults and appearance, largely by children. However, Ejumula the best variety suffers from viral infections and is affected by prolonged drought, resulting in scarcity of planting material at the on-set of rains. These studies have introduced more adapted, high yielding, disease resistant and equally acceptable OFSP varieties.

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The potential for storage of fresh sweetpotato under tropical conditions: Evaluation of physiological changes and quality aspects

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Abstract. This paper presents the results of two years of trials carried out on-station at Lake Zone Agricultural Research and Development Institute, Tanzania and gives recommendations for simple and low cost storage of fresh sweet potato. The optimum conditions for long term storage of sweet potato are well known, but little is known about the conditions in simple storage structures or if it is possible to influence them. To evaluate this, five different treatments were assessed. These were: effect of cultivar (SPN/0, Polista and Sinia B); level of root damage; lining with dried grass; ventilation; and store design (pits or clamps). Over a period of 18 weeks, the physiological changes of the roots in the stores were monitored via oxygen and carbon dioxide levels, relative humidity, temperature and root weight. The quality of the stored roots was assessed by sensory evaluation, external appearance and estimated market value. High temperatures and high weight loss of the roots indicated deterioration

during storage. This was most strongly associated with storing damaged roots as opposed to good quality ones. Store type (pit or clamp) or ventilation did not have a consistent effect on shelf-life and suggests that any combination of these designs can be used. Sensory properties may change during storage and acceptable characteristics were found up to 12 weeks of storage. Stored roots may taste sweeter than freshly harvested roots. Success of storage, however, is also determined by other factors than just store design and this is discussed.

Probiotic and prebiotic properties of lactic acid bacteria isolated from cassava fermentations

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Abstract. This work was a preliminary investigation of the putative prebiotic and probiotic properties of lactic acid bacteria (*Lactobacillus* sp., *Pediococcus* sp.) isolated from cassava and sorghum fermentations. Exopolysaccharides produced by a small number of isolates were tested for their ability to stimulate *Bifidobacterium*, but not *Escherichia coli* or *Clostridium perfringens*. At the same time, a number of isolates were screened for basic probiotic properties (resistance to stomach acidity and bile) and for production of specific anti-microbial agents. Results showed that EPS produced by some isolates was fermented by *Bifidobacterium*, but not by *Escherichia coli* or *Clostridium perfringens*. At the same time the basic probiotic properties of resistance to stomach acidity and bile could be demonstrated. Some isolates also produced anti-microbial compounds. In the present

study, however, isolates producing EPS with prebiotic properties were not those producing anti-microbial compounds. Although considerable substantiation is required, isolates of lactic acid bacteria (LAB) from cassava and sorghum fermentations appear to have considerable potential as both probiotic and prebiotic ingredients in foods. These properties could be exploited either to enhance the nutritional value of existing foods, such as cassava, or in development of new food products based on traditional foods.

Nitrogen fertilizer application timing in ‘beauregard’ sweetpotato

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Abstract. Although sweetpotato storage root production is acceptable without supplemental nitrogen (N) fertilization, yields are only a fraction of the yield potential for certain cultivars. Incremental rates of fertilizer N application generally result in proportional increases in storage root yield up to a certain level of N. In certain situations, the addition of fertilizer N does not elicit any yield response. This lack of yield response to a range of fertilizer N is attributed to several factors including microorganism activity, differences in N mobilization and immobilization, leaching, dinitrification, volatilization, residual N, cultivar effects, and application timing. Application timing, including split applications may increase N use efficiency and possibly achieve yield response with added N. Evaluation of the response of ‘Beauregard’ to seven application timing treatments (50 kg·ha⁻¹ pre-plant, split [25 kg preplant+25 kg 28 days after transplant, DAT], 21, 28, 35, and 45 DAT) indicate that split application had the highest U.S. No. 1 storage root yield, resulting in 25% and 38% increase over pre-plant and 0 N applications, respectively. This was followed by 21 DAT (20%, 33%) and 28 DAT (3.4%, 9.8%). Applications at 35 and 45 DAT generally resulted in yield reduction (-10%, 8%) and (-32%, -9%), respectively. The results show that application timing suggests a more efficient use of N fertilization in ‘Beauregard.’ Application beyond 28 DAT generally results in yield reduction. The results provide growers with management options that increase fertilizer N efficiency.

The effect of orange fleshed sweetpotato on vitamin A and nutritional status of pre- school children in Nambale division Busia district

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Abstract. An interventional study was carried out to determine the effectiveness of orange-fleshed sweetpotato in improving the vitamin A status of pre-school children. The study was conducted in Busia District of Western Province, Kenya. The trial lasted 60 days in a primary school that was purposively selected. The children involved were from middle and low socio-economic status, and were aged between 3 and 7yrs. All the children were treated with SP anti-malarial and de-wormed with mebendazole tablets before and towards the end of the intervention. Two intervention groups were identified among children who met the selection criteria. Baseline and final data were collected from these children and their families. Data were collected for blood haemoglobin levels, erythrocyte sedimentation rates, malaria parasites, serum retinol, serum zinc, and total carotenoids. Additional data and anthropometrical measurements were also taken.

Introduction

Vitamin A deficiency (VAD) is an important cause of blindness in children. It is known that mild or sub-clinical VAD causes impaired immune function (Semba *et al.*, 1994) and increases the risk of mortality from infectious diseases (Sommer *et al.*, 1984; Fawzi *et al.*, 1993). Many developing countries have VAD as a public health problem due to inadequate intake of vitamin A from food (Underwood, 2000). The prevalence of vitamin A alone in children under five is 84% (Mwaniki *et al.*,

1999). Food-based strategies such as food fortification, dietary diversification through home gardening and school health programmes are some of the strategies being used in Kenya. Dietary vitamin A is available as preformed vitamin A, in animal products, and provitamin A carotenoids is found in orange-colored fruits and vegetables. Orange-fleshed sweetpotato (OFSP) are known to be rich in carotenoids especially beta-carotene (Jan Low *et al.*, 1997). Work done by the International Potato Center (CIP) and Kenya Agricultural Institute (KARI) in Nyanza Western Province of Kenya indicates that feeding children daily with OFSP could ensure that the recommended daily allowance for vitamin A (RDA) is achieved. This study was therefore undertaken to ascertain the importance of using OFSP to maintain the vitamin A status of pre-school children in Nambale Division, Busia district, Kenya. The main of the study was to determine the effectiveness and contribution of the orange-fleshed sweetpotato porridge on the vitamin A status of pre-school children in Nambale Division, Busia District. Specifically, the study sought to (i) determine the socio-economic and social demographic characteristics for the selected households of pre-school children in Nambale Division Busia District; (2) determine the morbidity patterns and experience in the selected pre-school children during the intervention; (3) determine the type, frequency and quantity of intake of vitamins A rich food sources by the pre-school children; (4) carry out

proximate analysis of OFSP flour for carotenoids; (5) determine baseline and post-intervention micronutrient status (specifically serum retinol, total carotenoids, serum zinc and haemoglobin levels and malaria parasite count) of pre-school children in Nambale Division Busia district; and (6) determine the nutrition status (anthropometrical measurements) among the selected pre-school children.

Research Methodology

Study area. The study took place in Busia district (K), Nambale Division. Busia district is in Western Province of Kenya. The District borders westwards with the Republic of Uganda. Nambale has an area of 232.5 square kilometers and its permanent water source is L. Victoria and has a population of 67,544. The main economic activity is agriculture with emphasis on food crops namely; sweetpotato, maize, cassava, groundnuts, indigenous vegetables, millet, maize, simsim, bananas and beans. Some people engage in petty trade. Malaria is holoendemic in this area.

Subjects. The study targeted pre-school children in the early childhood care and development centre (ECCD) aged 3 – 7yrs. Blood samples were collected from the subjects for analysis.

Variables in the study. Children were divided into two groups of 85 each. One group was fed on OFSP and the other on white-fleshed sweetpotatoes (WFSP) based porridge. The variables analyzed at baseline and post-intervention phases included serum retinol, serum zinc, haemoglobin levels, total carotenoids, malaria parasites and erythrocyte sedimentation rates.

Beta-carotene in food and serum was quantitatively determined using High Performance Liquid Chromatography (HPLC) at 445 nanometer (nm) after a homogenization and extraction procedure. Serum retinol was

determined after deproteinization of serum with methanol and subsequent extraction using hexane. Haemoglobin levels were determined using the haemocue photometer. For malaria parasites, thick and thin blood smears were made, stained with Giemsa, fixed with methanol and parasites counted and expressed per micro-litre (μ l) of blood. Serum zinc was determined using atomic absorption spectrophotometry.

The Winthrop method was used to determine erythrocyte sedimentation rates. A haematocrit tube was filled to the 100 mark with oxalated blood and allowed to stand vertically for one hour and the sedimentation rate determined using a chart specially prepared for this purpose.

Anthropometrical measurements were taken before blood sample collection. The weights and heights of the children were taken and presented as Z-scores. Mid upper arm circumferences of the study children were also measured.

Dietary assessments. The pre-tested questionnaire was administered to the children. The questionnaire was meant to determine the unquantified food frequency, 24 hr dietary recall, socio-demographic and economic parameters. Other issues captured by the questionnaire were about health and food security.

Focus group discussions. Focus group discussions with 8-10 women were conducted to enrich the information collected through the questionnaire.

Training and sensitisation of cooks and ECCD teachers. The ECCD cooks and teachers were introduced to the study. The importance of sticking to procedures, monitoring issues, compliance by children and recording of absenteeism and morbidity were emphasised. The school had three resident monitors and two cooks. The monitors were

teachers already familiar with the children, and the cooks were the taken from those employed by the school.

Standardization of the feeding regimen. The feeding regimen was first cooked and standardized in the Kenya Medical Research Institute (KEMRI) nutrition laboratory. The feed for the experimental groups was prepared in such a way to provide 100% RDA of vitamin A (in this case 300 RE µg), the maize and soy bean flours were calculated taking into consideration the calculated amounts of ingredients for basic mixes based on the edible portions of food. In this case where the staple is maize, the feed included 20gm of maize flour per serving per child supplemented with 10 gm of soybean flour. The amount of OFSP and traditional white-fleshed sweetpotato (TWFSF) flour was 150 gm for both, 50 gm of which included to cater for the inevitable losses.

Each child was given 500 ml of porridge in a day in two portions i.e., in the morning and afternoon. The parents of experimental children were advised not to give OFSP at home (this could interfere with the vitamin A consumption in the porridge). Otherwise the parents were advised to feed their children the normal meals at home.

RDA for zinc sulphate for this age category (3-7yrs) is 7.5mg. Since the children's diet is basically cereal and legume based in which the phytate content is definitely high, there was need to adjust the zinc sulphate amount to cater for the difference. Therefore, 15mgs of zinc sulphate solution was included in the porridge for 60 days (8weeks). The composition of the porridge for the two study groups is shown in Table 1.

De-worming and treatment of malaria and low haemoglobin levels. All the children were dewormed twice according to the procedures of the Integrated Management of childhood Illnesses (IMCI) guidelines. Children 2 years and above who had not been dewormed in the previous 6 months were dewormed using 500mg of mebendazole. They also received

malaria treatment according to the National Malaria Control Council guidelines (one and a half tablets of SP oridor were given). Those with severe anaemia were referred to the nearest health facility for treatment.

Procedure for processing flour for the porridge. The potatoes were first washed and then chipped using the potato-chipping machine at the FTC. The potato chips were then dried on canvas for a maximum of eight (8) hours. Dry chips were then milled, the flour weighed, labeled and transported to the school.

Supply of ingredients for porridge preparation. Ministry of Agriculture and Kenya industrial research institute (KIRDI) trained some local women to process the flours that were used in the study. The flours were packed in weekly portions for specific groups. Sugar, oil and zinc sulphate was bought and also supplied on weekly basis.

Preparation of the feeds. The porridge was prepared in the normal way using the usual utensils. The measurement and mixing of ingredients was however, closely supervised. The porridge was served to children at 10:30a.m. The study children (participating) ate first followed by the non-participating ones. Each child was given 500mls of porridge and supervised until each drank up all the porridge.

Monitoring for compliance. The children were made to sit down on mats in a circle. A coloured band was tied on each child's wrist to identify

Table 1: Feed components of the two study groups.

OFSP based porridge	WFSP based porridge
1. OFSP = 150gm	1. TWFSF = 150m
2. Sugar – 5gm	2. Soya bean -10gm
3. White maize – 20gm	3. Sugar – 5gms
4. Oil – 5gms	4. Oil-5gm
5. Zinc Sulphate supplementation	5. Zinc Sulphate supplementation

each of them by group. The children were again fed in the afternoon before they left for home. The teachers marked everyday against every child's name for compliance. For example, records were kept for children who were sick, those who did not finish the feed, and the reason for non-compliance also given. The feed was given 6 days in a week excluding holidays. Compliance was defined as the number of days a particular child received and drank the porridge, and was expressed as a percentage of the total number of potential porridge days.

Collection and recording of morbidity data.

Morbidity data was collected daily during school weekdays until the last day of the trial (60th day).

Collection of sweetpotato samples and the feed for analysis of carotenoids. The OFSP flour and the prepared porridge were taken to the laboratory for proximate analysis.

Quality control. The project was strictly monitored to ensure that all study procedures were adhered to. It was also aimed at providing immediate solutions to problems that arose.

Results and Discussion

Percentage distribution of age groups in the study area. Children below 14 years of age were 60.3%; while adults (15-64 years) were 39.1%. Women of reproductive age were 37.5%, while the aged were only 0.4% (Table 2).

Table 2: Socio-demographic and socio-economic results.

Age	Category	Percentage
Below 14yrs	Children	60.3
15-64 yrs	Adults	39.1
65 plus	Aged/Geriatric	0.4
15-49yrs	Women of reproductive age	37.5

Household size. The mean household size was found to be 6.05 with a median of 6.0. The minimum and maximum were 2 and 12, respectively. Compared to the National Fertility Rate (FTR) of 5.4, the household sizes in Nambale FTR were slightly higher.

Respondents. The male respondents were 49.2% (92.4 % were head of households) while women respondents were 50.8 % (7.8% of these were heads of household). Responses were mainly obtained from women.

Religion. Most families in Nambale are Roman Catholics (61%) followed by Protestants (32.7%). Among these 32.7% were males while females were 32.8. %. Muslims and Seventh Day Adventists were 3.7% and 2.5%, respectively. In all these groups women were slightly more than men.

Education. The pre-schoolers in Nambale division were 21.9%. Of these, 9.2% did not attend school. Overall, most of the people in Nambale never studied above upper primary level.

Occupation/type of work. Permanently employed adults in the study area were 3.5%. The un-employed were 32.7% while those on temporary employment were 10.0%. Most of the families in this area are farmers (25.9%). The others are artisans (1.4%), casual labourers (2.8%), teachers (1.0%) and businessmen (3.4%).

Morbidity. The causes of morbidity were reported as malaria (92%), cough (82.9%), worms (53%), diarrhoea (47%) and measles (19%). Others were: fever (17.1%), scabies (12.9%), flu (12.4%) and malnutrition (7.%) (Table 3).

Food frequency. Foods were categorized in seven groups as follows: cereals, starchy tubers/roots/fruits vegetables fruits, legumes oil/oil seeds/nuts, animal proteins, fats and oils and the miscellaneous. Among these food groups the cereals were most frequently

consumed, (54%), followed by green vegetables (31%), animal proteins mainly small fish (26.5%), fruits (23.5%) (mainly avocados) and starchy fruits/tubers/roots (23.5%) among others (Table 4).

Table 3: Morbidity patterns in ECCD children.

Illness	Percentage
Malaria	92.4%
Cough	82.95
Worms	53.5%
Diarrhea	47%
Measles	19%
Fever	17.1%
Scabies	12.9%
Flu	12.4%
Malnutrition	7.1%
Boils	6.5%
Night blindness	2.4%

Health and nutrition. The highest morbidity was malaria. The fully immunized children were 90.0%, while those who had received vitamin A were 90.0%. Most children had received vitamin A doses in June 2002 when the National Immunization Days (NIDS) exercise was on. The anthropometrical measurements for both the orange and the white group (weight for age and height for age) indicated a positive change.

The majority of the children had their serum retinol levels above 0.70mmol/l (Table 5). There was also no significant change in total serum carotenoids (Table 6). This was most likely due to the loss of beta-carotene during the processing of the potatoes into flour, storage and also during cooking. Most erythrocyte sedimentation rates (ESR's) were all elevated (Table 7) suggesting the presence of infection or illness with less improvement attributed to the intervention. Of all the children, 24.7% were below -2SD (HAZ), 9.4%

Table 4: Frequency of consumption of different foods in the study area.

Food category	Type of food (%)	Daily intake (%)	Twice per day (%)	Thrice per day (%)	Four times a day (%)
Cereals	Staple porridge	54	21.1	6.5	0
Starchy Tubers/Roots/Fruits/Vegetables	Cassava	22.4	10	0	0
Vegetables	Cowpea- leaves (kunde)	31.8	2.4	0	0
Fruits	Avocado	23.5	5.9	0.6	0
Legumes/Oil Seeds/Nuts	Beans	7.1	1.2	0	0
Animal Proteins	Small Fish	26.5	4.1	0	0
Fats and oils	Kimbo	11.6	38.2	0.6	0
Miscellaneous	Sugarcane	4.7	13.5	0	0

Table 5: Effects of the daily feeding intervention of OFSP and WFSP on serum retinol levels of 170 children for 8 weeks (mean 95% confidence interval)

Serum retinol umol	Feeding intervention		P Value
	Orange group n=84	White Group n=79	
Baseline	1.00 (-1.05, +1.07)	1.08 (-1.06, +1.09)	0.6007
8 weeks	0.99 (-0.91, +1.00)	1.03 (-1.02, +1.04)	0.6437
Change	-0.01	-0.05	
Difference	-0.05 (-0.08, +0.06)		0.8444

below -2 SD (WAZ), while 2.4% were below -2 SD (WHZ). Malaria was among the top 10 diseases reported in Nambale. Haemoglobin levels showed a shift towards improvement (Table 8) .

Nearly all the children in the two study groups had malaria parasites. During both baseline and final physical examinations a few

of the children had elevated temperatures and were treated for malaria. The study area being in a malaria endemic and vitamin A deficient zone, it was quite surprising because the serum retinol level were higher than expected. The last vitamin A supplementation in this area had been done in June 2002. The dietary intake for the households in the study suggest

Table 6: Effects of the daily feeding intervention of OFSP and WFSP on total carotenoids of 170 children for 8 weeks (mean 95% confidence interval).

Carotenoids ug/dl	Feeding intervention		P Value
	Orange group n=81	White Group n=79	
Baseline	131.36(-201.35,463.85)	127.73(-163.02, +418.48)	0.9040
8 weeks	129.32 (-124.76, +383.4)	126.18 (-177.14, +429.50)	0.4372
Change	-2.04	-1.55	
Difference	0.13(-394.98, +389.06)		0.9612

Table 7: Effects of daily feeding intervention of OFSP and WFSP on erythrocyte sedimentation rates in 170 children after 8 weeks (mean 95% confidence interval)

ESR mm/hr	Feeding intervention		P
	Orange group n=80	White Group n=79	
Baseline	23.77 (-0.91, +48.45)	23.18 (-0.19, +46.55)	0.7847
8 weeks	25.55 (-9.62, +49.48)	25.87 (-8.71, +43.03)	0.0818
Change	1.78	2.69	
Difference	0.91 (-22.87, +33.87))		3460

Table 8: Effects of a daily feeding intervention of OFSP and WFSP on hemoglobin concentration in 170 children after 8 weeks (mean 95% confidence interval).

Hemoglobin g/l	Feeding intervention		p
	Orange Group n=85	White Group n=81	
Baseline	114.53 (-112.65, +116.32)	116.80 (-116.70, +118.24)	0.3160
8 weeks	117.10 (-115.21, +118.99))	120.00 (-118.82, +121.17)	0.3429
Change	2.57	3.2	
Difference	0.63 (-0.09, +0.028)		0.2126

that the highest intake was from cereals. Vitamin A from plant sources has a problem of bio-availability and bioconversion.

Data collected on meals intake during wet and dry seasons revealed that snacks are not commonly given to children in this community, while dinner is more valued than breakfast and lunch. During dry seasons the consumption of breakfast and lunch are affected. The the number of meals reduces. The food frequency questionnaire revealed that porridge was consumed on a daily basis in many households (54%). Other foods consumed were white tea (35.5%), cowpea leaves (31.8%), kale (25.9%) and small fish (26.5%).

Conclusion and Recommendations

Until all data is analyzed, it will not be possible to conclude on the efficacy of the orange-fleshed sweetpotato porridge. However there are indications of a change towards improvement of individual children's nutrition and health status. The serum retinol levels were generally maintained throughout the study; pointing positively at the feeding intervention and the treatment of malaria and de- worming of the children. From the study, we recomend more bio- efficacy research

using the OFSP; doing a similar study in another area with the same age group; and introduction of OFSP and more food based strategies in the school feeding programmes to combat VADD.

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Vitamin A for Africa (VITAA): An entry point for promoting orange-fleshed sweetpotato to combat vitamin A-deficiency in sub-Saharan Africa

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Abstract. In sub-Saharan Africa, 640,000 children die each year from causes associated with Vitamin A deficiency. Improvement in Vitamin A intake would contribute to the Millennium Development Goal (MDG) of reducing by 20% the mortality rate of children less than five years of age. The VITAA partnership (Vitamin A for Africa) is dedicated to alleviating the suffering caused by vitamin A deficiency using orange-fleshed, beta-carotene-rich sweetpotato that meet African standards for taste and texture. A recent *ex ante* impact case study conducted by the International Potato Centre and Michigan State University suggested that 50 million children under six could benefit from the new varieties. The VITAA initiative is aimed at making orange-fleshed sweetpotatoes available on a large scale, demonstrating the potential of crop-based approaches in alleviating micronutrient deficiencies. VITAA member countries include: Tanzania, Uganda, Kenya, Ethiopia, Mozambique, South Africa and Ghana. VITAA objectives are to: complement development agencies' food supplementation/fortification efforts; increase the capacity of national agriculture, health and nutrition experts to incorporate sweetpotatoes in their national dietary recommendations; stimulate and promote micro-enterprise development using products made from orange-fleshed sweetpotatoes; teach house hold managers (women and children) the nutritional value and benefits of consuming orange-flesh sweetpotatoes. To-

date a selected number of adaptable and acceptable varieties have been disseminated to major production zones in SSA countries through non governmental organizations (NGOs) and community based organizations (CBOs), with more releases expected. VITAA strength is based on the building of partnerships with a variety of stakeholders. This paper discusses progress to date and lessons learned.

Background

Vitamin A deficiency (VAD) does not kill its victims directly. It weakens the immune system leaving them susceptible to diseases such as measles, malaria, and diarrhea. Those most severely affected are young children and pregnant and lactating women. In sub-Saharan Africa, 3 million children under the age of five suffer from a vitamin A-related form of blindness known as exophthalmia, or dry eye, and many, many more are at risk. Two-thirds of those affected may die within months due to the collapse of the immune system. Worldwide, an estimated 250 million pre-school children may be deficient in vitamin A. Public health experts believe that addressing the problem could reduce overall mortality among children under six by more almost 25 percent. Studies also show dramatic reductions in maternal mortality when pregnant women receive vitamin A or beta-carotene supplements.

Over the past 25 years, public health agencies have addressed VAD by providing children with vitamin capsules that contain mega-doses of Vitamin A. The strategy has helped millions, but has proven expensive and, despite the best efforts of those involved, has left hundreds of thousands of children at risk.

As a complement to vitamin supplements, health experts have experimented with different methods that address the problem through diet. Many types of fruits and vegetables, as well as meat and milk, are rich in Vitamin A or beta-carotene, and, if consumed in sufficient quantity can eliminate or greatly reduce the impact of VAD. Most foods that are rich in Vitamin A, however, are too expensive for African consumers, are only seasonally available, or are unpalatable to young children. The exception is sweetpotato, a highly productive food crop that has few natural enemies and is widely grown in Eastern and Southern Africa.

The experience that sowed the seeds of VITAA came in the mid-1990s, when the Kenya Agricultural Research Institute (KARI), the International Center for Research on Women (ICRW), the NGO CARE International and CIP came together in a pilot project to find out whether orange-fleshed sweetpotato would appeal to African consumers. Until then it had been assumed that few would be willing to switch from the traditional white-fleshed varieties, which are high in starch and energy and have good cooking qualities because of their high dry matter content. To our delight, the project banished the myth of consumer un-acceptability; both women and children welcomed the taste and texture of the orange-fleshed sweetpotato (OFSP). Children in particular loved the sweetness and the orange like juiciness.

On 9 May 2001, an international group of 70 agriculturists, health experts and nutritionists launched what is believed to be the first crop-based initiative to attack the tragic consequences of vitamin A deficiency in Sub-Saharan Africa. The initiative is known as VITAA, or vitamin A for Africa. Working

under the VITAA umbrella, 40 partner agencies from the health, nutrition and agricultural sectors agreed to work together to extend the impact of orange-fleshed sweetpotato in seven partner countries: Ethiopia, Kenya, South Africa, Tanzania, Uganda, Mozambique and Ghana. The VITAA goal is to create healthy rural populations through food-based approaches to nutrition focused on vitamin A.

VITAA partnership provides community groups in the SSA countries with new orange-fleshed varieties that prevent vitamin A deficiency. VITAA recognizes orange-fleshed sweetpotatoes as a promising solution to vitamin A deficiency in Eastern and Southern Africa not just because they're rich in beta-carotene, but because they're easy to grow and affordable to the average consumer. Unlike Africa's traditional white-yellow fleshed sweetpotatoes, VITAA varieties are rich in beta-carotene, a micronutrient that the body uses to produce vitamin A. VITAA is coordinated by the International Potato Center, the CGIAR research center based in Lima, Peru.

VITAA works at the community level, targeting mother's groups and other producer organizations in areas where sweetpotatoes are already grown.

VITAA OFSP varieties are rich in beta-carotene that the body uses to produce vitamin A. A recent ex-ante impact case study conducted by economists from the International Potato Center (CIP) and Michigan State University strongly suggests that 50 million African children under the age of six could benefit from the new orange-fleshed varieties. A complementary field study conducted by CIP and the International Center for Research on Women (ICRW), a VITAA partner agency, noted that in western Kenya: orange-fleshed sweetpotatoes and sweetpotato-based food products were not only acceptable to both producers and consumers in terms of appearance, taste, and texture, but contributed to the alleviation of vitamin A deficiency. The new sweetpotatoes performed well with respect to yield and pest

resistance and also had high beta-carotene content. One of the principal findings from the study was that African mothers would readily accept the new varieties, dispelling the myth that African taste preferences precluded the use of orange-fleshed varieties. The study also demonstrated that the daily addition of as little as 100 grams of OFSP to the diet could prevent VAD in children, pregnant women and lactating mothers. A major bio-efficacy study conducted by South Africa's Medical Research Council earlier this year reached similar conclusions.

VITAA currently works with collaborating agencies in Ethiopia, Ghana, Kenya, Mozambique, South Africa, Tanzania, and Uganda. Each of these countries is working hard to introduce orange-fleshed varieties, but efforts are probably most advanced in Uganda, where a host of regional organizations and NGOs are promoting the adoption of the new VITAA sweetpotatoes at the community level.

Now the partnership is capitalizing on the opportunity revealed by these findings. Adaptive research activities are being advanced in Kenya, Mozambique, Ghana, Tanzania, South Africa, Ethiopia, Madagascar, DR. Congo, Rwanda, Zambia, Malawi, Burundi and Uganda, where the NARIs scientists are working with CIP's regional staff to screen several orange-fleshed varieties in order to access their suitability to different environments. In addition, NGOs and women's groups in all countries are participating in on-farm trials, exposing a growing number of producers and consumers to their first experience of the varieties.

Farmers also found that the new orange-fleshed varieties grow well, have acceptable root yields and are moderately resistant to stresses such as drought and insect pests. Results of the assessments indicate that all varieties tested had a great potential for acceptability although the first batch was highly attacked by sweetpotato virus disease (SPVD). The variation between rankings for the various attributes both within and between agro-ecologies by farmers was not

much. The fact that OFSP varieties were liked by the consumers more so ranked high by children implies that these can be easily adopted among the farming communities in Africa. Markets of OFSP (roots, processed chips and vines) and multiplication and distribution of planting materials have continued to rise as a result of individual farmers' and community-based organizations' efforts. For instance, in Western Kenya, more than 18 million vine cuttings mainly of OFSP varieties have been distributed to farmers through partners in the region.

Potential of orange-fleshed sweetpotato in combating Vitamin A deficiency in SSA. The promotion of orange-fleshed sweetpotato is showing great promise as a key element in strategic partnerships to solve the problems of malnutrition and food insecurity in eastern and southern Africa. Sub-Saharan Africa (SSA) is the only region in the developing world where both the number and proportion of malnourished children has been consistently rising. According to projections in IFPRI's 2020 Vision project, the number of malnourished children is projected to rise from 33 million in 1997 to between 39 and 49 million in 2020, depending on the model used (Rosengrant *et al.*, 2001).

In SSA, three million children under the age of five suffer total or partial blindness caused by Vitamin A deficiency (VAD). Vitamin A is consumed directly in meat products, and is produced in the body if a person consumes sufficient quantities of a precursor known as β -carotene. Otherwise, the body cannot produce sufficient Vitamin A. Vitamin A deficiency is particularly a problem among children under five and pregnant and/or lactating women. Serious VAD can lead to blindness; chronic deficiency reduces a child's immune system to fight off malaria and other diseases

Development and health agencies have reacted to this crisis by distributing Vitamin A capsules and fortifying processed and packaged foods. The results have been impressive. More than 12 million children

received Vitamin A supplements in 1997, and the total number of children suffering from blindness related to severe vitamin A deficiency has dropped. Nevertheless, many families, particularly in rural areas, do not have access to capsules or fortified foods. In these areas therefore, Vitamin A chronic deficiency is rife. In circumstances where use of capsules and fortified foods to mitigate the situation is not possible, the use of orange-fleshed sweetpotatoes seems feasible. Sub-Saharan Africa produces over 7 million tons of sweetpotato annually, about 5 percent of global production. Recent projections indicate that production will more than double by 2020, whereas production in other regions is expected to remain stable or take decreasing trends. Sweetpotato is an important household food security crop in eastern and southern Africa, particularly in densely populated, intensively cultivated mid-elevation farming areas. Although the crop is mainly cultivated for domestic consumption, both fresh roots and leaves are increasingly gaining market potential for cash income. Roots are commonly consumed fresh, mostly just boiled or roasted, and the range of common recipes is narrow. Most sweetpotato varieties grown in Africa have white- or yellow-coloured flesh, and supply little or no Vitamin A. Orange-fleshed varieties introduced from other parts of the world or bred locally have been readily accepted in pilot areas in East Africa, and preliminary results have shown that they contain sufficient levels β -carotene to play an important role in eliminating VAD (Hagenimana *et al.*, 1999).

Ex-ante impact study. An impact case study conducted by economists working at Michigan State University and CIP suggests that orange-fleshed sweetpotato could significantly help prevent vitamin A malnutrition in sub-Saharan Africa and could eventually benefit some 50 million African children.

According to the study, in countries such as Rwanda, Burundi and Uganda, where sweetpotato production is already high, full

adoption of orange-fleshed sweetpotato could resolve vitamin A deficiency completely for 85 to 95 % of children most at risk in addition to significant benefits for childbearing women.

Even in countries that are not major sweetpotato producers, such as Ethiopia, a third of the population would enjoy partial benefits from enhanced beta-carotene intake as a result of switching from white- to orange-fleshed varieties.

Fortification of food crops such as sweet potato with higher levels of micronutrients – a process known as bio-fortification can be a powerful tool in combating nutritional deficiencies. However, there is a lot of optimism that it will benefit large numbers of people in the years to come. IFPRI and the International Center for Tropical Agriculture, head HarvestPlus, a new CGIAR initiative working to fortify major developing country staples, such as beans, cassava, maize, rice, wheat, and sweetpotato. The VITAA experience serves as a model for these efforts, providing concrete evidence of the effectiveness of food-based approaches in tackling micronutrient malnutrition.

Adaptive research on orange-fleshed varieties. A series of adaptive research and pilot extension activities have been conducted to provide the project with information in several key areas. To-date the stage for large-scale diffusion of the new varieties has been set with the target of scale-up by 2005. Activities done in collaboration with farmers mainly women groups include: a) studies that further define role of the new varieties in the family diet; b) efforts to establish micro-enterprises and micro-credit schemes; c) the testing of on-farm processing techniques, including the enrichment of local weaning foods; d) pilot testing of rural seed multiplication and distribution systems, and e) the provision of superior breeding lines. To-date ten to twenty OFSP varieties with high dry matter have been accepted consumers in the region. Fourty new clones

are being tested widely in all VITAA partner countries for adaptability and acceptability

Before the VITAA initiative, it had been assumed that few consumers would be willing to turn away from the traditional white-fleshed varieties, which are high in starch and energy and have good cooking qualities because of their high dry matter content. To our delight, the OFSPs were acceptable to both adults and children. Children in particular loved their sweetness and the orange like juiciness.

The partnership is now capitalizing on the opportunity revealed by these findings. Adaptive research activities are being advanced in Kenya and Uganda, where KARI and the National Agricultural Research Organization (NARO) scientists are working with CIP's regional staff to screen several orange-fleshed varieties for their suitability to different environments. In addition, NGOs and women's groups in both countries are participating in on-farm trials, exposing a growing number of producers and consumers to their first experience of the varieties. A number of orange-fleshed varieties are currently being multiplied and cleaned for viruses by CIP at Muguga Plant Quarantine Services in Kenya for distribution to different sub-Saharan countries.

In Luwero district Uganda, children loved the taste, texture, and color of *Ejumula*, a deep orange variety, while adults preferred the lighter orange *Kakamega* variety, which is less sweet and has much appealing flavour. Additionally, these varieties grew well, had acceptable tuber yields were moderately resistant to stresses such as drought and insect pests (CHDC, 2001). These results imply that these varieties can be easily adopted in Luwero. According to children, *Ejumula* had a very attractive color, sweeter and less fibrous whereas for the adults, the most preferred variety was '*Kakamega*' (SPK004). It was flourier and not sugary like *Ejumula*. Field attributes like resistance to pests, drought tolerance and time to maturity were ranked high by the farmers. Similarly, all varieties were ranked above moderate for the

tuber yield attributes. Throughout the five villages where the study was done, *Ejumula* and *Kakamega* (light orange/cream) were the most preferred varieties.

In addition to the above, farmers in Kenya, Tanzania and Uganda have evaluated other orange-fleshed and other preferred varieties.

Principles of the VITAA Work Plan. As a result of these highly promising results, representatives from the seven VITAA partner countries have agreed to promote orange-fleshed sweetpotato in each of the major production zones where white-fleshed varieties are most dominant. The work is mainly community-based and focuses on women decision makers. It also emphasizes nutrition education and micro-enterprise development. The partnership operates according to the following principles:

1. That orange-fleshed sweetpotatoes are now acceptable by African consumers and ready for full-scale development, and will also prove effective as an entry point for other food-based strategies aimed at reducing VAD in sub-Saharan Africa.
2. That VITAA varieties can empower local communities to help mothers and young children prevent VAD through their own labour and industry but also increase their incomes through value addition.
3. That VITAA provides a highly effective tool to address VAD among rural poor communities more especially children, pregnant women and lactating mothers.
4. That evidence exists that the VITAA varieties may also help to reduce the impact of anemia, measles, and malaria.

VITAA Agenda. VITAA's agenda consists of a coordinated set of activities in the major sweetpotato-producing countries of Eastern and Southern Africa. Its principal objective is to promote wide-scale production and use of

orange-flesh sweetpotato. The partnership program focuses on Uganda, Kenya, Ghana, Tanzania, South Africa, Mozambique and Ethiopia. Close linkages are also maintained with partner institutions in other countries through two regional root and tuber crops research networks: PRAPACE (ASARECA) and SARNET (SACCAR). Project activities include: ex-ante impact assessment, participatory testing of varieties for adaptation and acceptability, community-based multiplication of planting materials, nutrition education, post-harvest processing for market and for home consumption, promotion through social marketing, monitoring of impact on nutrition and health, and capacity building. Principal beneficiaries are young children and their mothers, the two groups most at risk for Vitamin A Deficiency or VAD. Implementation strategies concentrate on women because of their central role in the production and marketing of sweetpotato and other food crops used in the family diet. Country work plans have been developed with key stakeholders to identify interventions with the highest potential pay-off.

VITAA Action Points. To make VITAA technology ready for full-scale deployment over the next five years, the partnership members have organized themselves around the following six-point action plan:

1. The establishment of a steering committee from all sectors of the Partnership. To-date, members include the Micronutrient Initiative, the International Center for Research on Women, the non-governmental organization Catholic Relief Services and CIP, along with one member from each participating country;
2. The development of national action plans. These include issues on health, nutrition and agriculture;
3. The development of a comprehensive, integrated regional action VITAA;
4. The completion of an efficacy and bio-availability study to confirm the uptake and efficiency of beta-carotene from sweetpotato for conversion into vitamin A in the body;
5. The establishment of communication and social marketing strategies to promote and increase the utilization of VITAA varieties. The envisaged outputs for VITAA include:
 - (i) Sweetpotato varieties with good agronomic and nutritional traits plus local acceptance;
 - (ii) Sustainable local seed multiplication and distribution systems;
 - (iii) Processed products based on new varieties;
 - (iv) Microenterprises based on OFSPs;
 - (v) Community- and household-based action plans for combating VAD with OFSPs;
 - (vi) Partnerships of trained of trained professionals committed to OFSP food-based approach to VAD;
 - (vii) OFSP information systems and databases;
 - (viii) Public education; and,
 - (ix) Monitor and and evaluate all project activities and measure impact.

Impact Assessments, Monitoring and Evaluation. The IFPRI-CIP study completed in 2001 revealed that there is sufficient per capita production of sweetpotato in SSA. And as such, the introduction and diffusion of OFSP varieties is most likely going to have positive consequences for vitamin A deficient populations. From this study, up to 50 million children in the region could benefit significantly from the new OFSP varieties.

Planning and Constituency Building. Working from the results of the ex-ante assessment, project leaders have embarked on a program of constituency building. The objective is to garner support for the use of high vitamin A sweetpotato among national policy makers, as well as NGOs and development agencies working in agriculture, human health, and nutrition. This is intended to create dialog on how best to exploit the new varieties, determine where they complement existing nutrition programs, and chart out a course for their full exploitation.

Training. The sustainability of the initiative, following the research and implementation phase, can only be assured by building local capacity to exploit the new technologies. To the greatest extent possible, training programs have been and continue to be conducted in all major project areas, including impact assessment, seed multiplication, post harvest processing and marketing, micro-enterprise and micro-credit. Priority has always been given to the concept of training of trainers.

Social Marketing. To encourage adoption of new technologies, VITAA has also developed a social marketing strategy and action plan. Mothers and school-age children have been targeted with messages that create demand for the new varieties and associated food products. The social marketing component has also encouraged government, NGOs, and community-based organizations to take responsibility for the distribution of the high beta-carotene materials and for micro-enterprise development.

Selected key success stories from the fields: A case of Uganda

Innovation to tap high demand for orange fleshed sweetpotato program. *Nju ku Nju* literally meaning “house to house” is a code name of a program by Mr. Hakim Ssali, a resident of Kayunga district in Uganda, where he moves from house to house sensitizing farmers on the importance of OFSP. He ultimately sells the vines to farmers who get interested. Hakim picked interest in OFSP from his friend Mr. Rajab Setyabula a prominent progressive farmer from Luwero district.

Consequently, a promotion campaign in Kayunga town council was launched. Many people got interested and an estimated 30 bags each containing 900 vines were sold to farmers, schools, and a prison. By the end of 2003, sensitization and distribution of planting materials had covered 5 sub-counties in Kayunga district and 4 sub-counties in the neighbouring Mukono district. In 2004 the

program was extended to Jinja and Kamuli districts.

The working strategy is to sensitize farmers about the potential benefits of OFSP and encourage them to start growing them. While moving house to house Sali carries along planting materials, which are sold to interested farmers. To encourage and make it affordable for most farmers only 45 vines are sold at U.shs 500= .30 cents of US \$. These vines are sufficient to plant only 15 mounds. However, there are framers who get interested and can afford to buy more vines to establish bigger fields. These are allowed to buy a full bag of vines at U.shs 10000= US \$ 6. The bag contains 900 vines which are sufficient to plant 300 mounds of a garden. After two months, “Nju ku Nju” goes back and buys planting materials from the farmers who started with a bag of vines. These are expected to produce over 20 bags of vine cuttings. The program strategically buys only 18 bags from the framers leaving the balance for more multiplication. At this time a farmer is paid U.shs 5.000/ per bag, thus getting a total earning of U.shs 90.000. The program sells these vines to the new farmers visited, and earns U.shs 180.000. This is the money he pays transport costs and other requirements for the program to run before getting a profit magin. Meanwhile the farmers who started with 45 vines will generate a minimum of 900 vines at the end of the two-month period and are at this time advised to expand their multiplication beds. They can benefit from the purchases of the vines by the program after second round of multiplication.

Using hired motorcycles, two farmers have been able to traverse many villages in the operation area. They move along with fresh roots, flour and juice samples as well as education materials like calendars, and posters. They have opened location offices in different districts, which serve as physical contact addresses as well as stores for planting materials.

With this strategy Mr. Hakim has achieved a lot. Though without proper records, Hakim estimates to have sensitised over 10,000

farmers. Through the profits he has made, he has purchased a 2 acre piece of land and meets school fees for his children. Many other people have benefited from the initiative. He estimates that about 40 farmers have already benefited selling planting material to him while are a lot more now eat orange fleshed sweetpotato in their households. He is also more hopeful since his initiative has attracted attention and interest from the office of the Special Presidential Assistant for the Underprivileged Youth.

Farmers train fellow farmers in OFSP production and utilization.

Mrs. Joweria Sekiyanja is proud of her achievements during the year 2004. Her face beams with a smile as she narrates the achievements. “Last year I told you that I had paid schools fees for one of my children during one the school terms, but I have been able to pay school fees for four children throughout 2004” boasts Joweria. “As a wife who was entirely depending on my husband I feed proud for having made this” says a jolly Joweria. “I have began building a commercial house on the plot I bought last year using money from sales of sweetpotato fresh roots, vines as well as products” says Joweria. According to records available her group has sold planting materials worth over Ugshs. 19 millions (equivalent \$11,100). She locally processes and sells juice, doughnuts, pancakes and cakes out of sweetpotato on a daily basis, an activity she says earns her at least Ughs. 5000 as profit daily. “I have opened a savings account on which I deposit at least shs. 1000 per day” says Joweria. Similar gains have been made by other women in her group and she believes that OFSP activities have improved livelihoods of many women in her village.

Joweria attributes the achievements to a number of factors. First she worked hard to expand her fields to 5 ha a decision she took at the beginning of the year. Second, she has participated in a number of workshops and exhibitions during which she has made contacts with key partners. These include: workshop for Jinja district members of

parliament. National Agricultural Shows in Jinja, World Food Day celebrations in Masaka, National Trade show at Lugogo, and the Launching of Poverty reduction program by the president at Katoke Luwero.

“The workshop for Parliamentarians was important for me. Many MPs especially women MPs got interested in my work and later contacted me to train their women groups in their respective areas” Says Joweria. According to her records, she has trained over 30 groups on request of members of parliament and other organizations. “We also got a juice sieving machine as a prize during the national trade show”, she reported. Recently she had yet another important opportunity where she interacted with the President of Uganda when he was launching a poverty reduction program in Katoke, Luwero. “The president spent 30 minutes asking me about the number of products I had exhibited despite a hurry move he made through other exhibitions” Joweria says with pride. She further asserts that the President later referred to and praised her work during the public address speech. The president then promised them a factory to expand on sweetpotato processing. She is hopeful that she will be successful because of the immense opportunities available.

Rural processing of orange-fleshed sweetpotato for food and income.

Mr. Ekinyu Eugene is the chairman of a rural processing group based in Abuket village, in Soroti district, North Eastern Uganda. The group is called “Abuket Orange-fleshed Sweetpotato Processors Association”. He acknowledges that he and his group are much better off since they began processing dried sweetpotato chips. His group was born out of a farmers’ group originally supported by an NGO, SOCADIDO, in sweetpotato production. They were experiencing yield surpluses but had limited markets. To avoid wastage, they would process sweetpotato using traditional means into *Amukeke*. However, the *Amukeke* had quality problems. Sweetpotatoes used to be sliced using traditional knives into big

slices that took long to dry and would therefore get mouldy. They were also dried on the ground resulting into a poor quality product. In addition, big slices were susceptible to storage weevils. To solve the above chain of problems, CIP together with its partners (particularly NARO and SOCADIDO) decided on piloting the rural based processing units made of groups with inteprenual interests and experiences. Thus Ekinyu's group was one of the two groups identified in Soroti district. The groups were trained in various aspects of quality processing and control of dried sweetpotato chips. A motorized chipper mounted with blades to slice sweetpotato into small chips that dried quickly was donated to the group through SOCADIDO during the launching of OFSP in Soroti district. The group went ahead and began processing sweetpotatoes into high quality chips. The group's first tone of dried chips was sold to Maganjo Grain Millers Co.

Women demand for “Babies Food” - orange fleshed sweetpotato in Hoima. Women in Hoima district are all out looking for a sweetpotato type called “Kirisabaana”. The word “Kirisabaana” is a term in the local language meaning “ that feeds children”. In Hoima district, the orange-fleshed sweetpotato were introduced through Bulindi Agricultural Research and Development Centre, a National Agricultural Research Organization (NARO) zonal institute. The Centre Manager of the Intitute reported that the promotion of orange fleshed sweetpotatoes was the institute's first success story. He also reported that in collaboration with Hoima District Farmers' Association, OFSP were very successssful in the distrct , that they ahd even spread to neighbouring districts.

VITAA Scoops A 2003 CGIAR Partnership Award. VITAA with its partners, has managed to introduce and popularise OFSPs in the region. During the 2003 Annual General Meeting of the Consultative Group on

International Agricultural Research (CGIAR) held in Nairobi, this VITAA effort was recognised. In this meeting, partners represented by individuals from Kenya and Uganda received the prestigious CGIAR award for the outstanding partnership and efforts to alleviate Vitamin A deficiency in Sub Saharan Africa.

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Summary of progress on orange-fleshed sweetpotato research and development in Ethiopia

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Abstract. Vitamin A deficiency (VAD) remains an important public health problem in developing countries like Ethiopia. Orange fleshed sweetpotato varieties have high contents of β -carotenoid and potentially can reduce the effects of vitamin A deficiency. To this effect, vitamin A for Africa (VITAA) was initiated. A planning work shop on “Combating VAD using OFSP” was held from which a production and promotion of OFSP against VAD” was developed. Other OFSP clones were undergoing preliminary yield trials. Out of these clones, clones like TIS-8250 (34.07t/ha) and Zapallo (33.35t/ha) were superior to the local check koka-12 (25.42t/ha). Activities to popularise OFSP varieties have also been undertaken through bazaar, workshop, public media and other extension means and have resulted in high demand for more OFSP cuttings.

Introduction

Ethiopia has 70 million people and is third most populous country in Africa. Sweetpotato is one of the most important crop for at least 20 million Ethiopians. The total area under sweetpotato in Ethiopia is 75000ha with an average productivity 8t/ha. White fleshed sweet potato is a staple food for 13 million people in the Southern Regional State.

Vitamin A deficiency (VAD) remains an important public health problem in Ethiopia just as in other developing countries. World Health Organization (WHO, 1982) classified Ethiopia as a nation where VAD was a public health and which could become worse due to recurring drought and hunger. International

agencies active in micronutrient deficiencies have advocated three different strategies to eliminate the VAD problems. These include dietary diversification, dietary supplementation and food fortification. The long term approach is the safest and most sustainable way of combating the problem in rural areas of developing countries where chronic deficiencies are common. This approach emphasises the consumption of vitamin A (VA) sufficient quantities of beta-carotene and VA rich food stuffs.

Even in years when food is plenty, the traditional food habit, of depending on cereals coupled with poverty does not allow the poor majority to get Vitamin-A rich foods. Moreover the limited infrastructure and inaccessibility does not allow the rural poor access Vitamin A capsules. As a result, infant and maternal mortality and night blindness are some of the commonest health problems in Ethiopia.

Due to these problems, the Ethiopian Sweet Potato Research and Development Program based at Awassa Agricultural Research Center in collaboration with CIP/PRAPACE launched breeding programme for Vitamin-A rich orange fleshed sweet potato (OFSP).

In fact before targeting to breed for Vitamin-A rich sweet potato against VAD, Ethiopia released two yellow/orange fleshed sweet potato varieties from local collections in the year 1987 and 1997 for root yield i.e. Koka-12 and AJAC-1 or Guntute with total root yield 25.4 and 35.35 t/ha, respectively. These varieties were not well adopted due to

their texture (moisty) and color. Even the case was not known for researchers at tha time.

Accomplishments

In the year 2001 a total of twenty OFSP clones were introduced from CIP-Nairobi and planted for open quarantine inspection and observation at Awassa Agricultural Research Center (AARC) in non-replicated observation plots. Thereafter, these clones were grouped based on maturity periods and planted in different agro-ecologies to observe them more closely.

Out of 20 clones, one clone (440201) was easily maturing (4 months) and had root yields of 10.17t/ha. Nine clones (187017.1, 56638, 440001, 440186, 420009, 440185, 440131, 440163, 440093) were medium maturing (5 months) with total root yield 5.57,5.39,4.72, 5.06, 4.56, 4.92,3.06, 2.44 and 2.24 t/ha, respectively. The remaining 10 clones were late maturing (Table 1). Destructive sampling indicated that the early maturing clones could

initiate and bulk before three months after planting. These can therefore fit in the short moisture areas. The yields of these materials were however very low because the trial was affected by drought (Table 4).

In 2001 participatory evaluation of OFSP clones was initiated. A total of 17 clones (Table 2) selected from existing germplasm based on flesh color was planted at Awassa, Wonago and Areka in a RCBD with three replications. A total of 12 clones were selected from this trial and planted again in 2002 following a similar design. In the 3rd year, the trial was repeated with an additional location, Chanomille. In both cases, agronomic and taste preference data was collected.

Among the OFSP high pro vitamin-A clones tested in 2001, Guntute and TIS 8250 resulted in 20.6 and 19.26t/ha root yield, respectively. The highest yield (23.4t/ha) was obtained from a white fleshed variety Damota. For this reason, it was not considered for promotion. In 2002, the highest root yield

Table 1: Orange fleshed Sweet potato clones introduced from Kenya and their maturity group.

S.N.	Clone	CIP No.	Total root yield/ha			Maturity class
			4 th month	5 th month	6 th month	
1	Narunmitang	440201	10.17	1.11	0.89	Early
2	Salyboro	187017.1	4.56	5.57	4.83	Medium
3	Jewel	56638	1.90	5.39	5.18	Medium
4	Resisto	440001	4.27	4.72	2.11	Medium
5	Tainung No 15	440186	2.27	5.06	3.89	Medium
6	Japon Tresmesino	420009	4.00	4.56	4.17	Medium
7	Lo-323	440185	0.67	4.92	1.44	Medium
8	Naveto	440131	1.17	3.06	1.33	Medium
9	Mugande	440163	1.09	2.44	1.67	Medium
10	NC - 1560	440093	1.67	2.22	1.11	Medium
11	VSP -	440288	2.67	3.44	6.91	Late
12	IITA-TIS-3290	440067	14.82	6.83	93.21	Late
13	Zapallo	420027	3.1	6.88	12.50	Late
14	Julian	440141	0.22	0.83	1.28	Late
15	Mugaba	440034	1.50	2.78	3.61	Late
16	Tanzania	440166	1.22	2.44	2.06	Late
17	Santo Amaro	400011	0.94	3.11	4.56	Late
18	Nemanate	420005	0.39	2.06	2.44	Late
19	Kemb 37	440170	1.39	2.78	4.39	Late
20	Taonung No 15	440186	2.60	5.79	7.68	Late

Table 2: Participatory evaluation of orange-fleshed sweet potato clones for high provitamin-A total root yield (t/ha).

Treatments		Year 1				Year 2		
		Awassa	Chano mille	Areka	Mean	Awassa	Wonago	Mean
1	TIB 11(02)	3.86	5.79	7.40	5.68	-	-	
2	CN 1108-13	11.81	3.24	6.98	7.34	-	-	
3	AIS 35-2	4.32	1.93	7.68	4.64	-	-	
4	TIS 5125 (112)	13.81	1.27	-	7.54	-	-	
5	TIS 8250	9.80	29.78	18.24	19.26	19.14	44.00	34.07
6	Guntutier	19.37	27.08	15.43	20.62	7.02	32.02	19.52
7	TIS 1487(20)	12.50	4.39	8.06	8.32	-	-	-
8	Dancota	13.04	36.38	20.79	23.40	8.26	37.58	22.92
9	192009 V	17.75	6.17	9.64	11.19	-	-	-
10	192040 II	5.02	10.49	3.97	6.49	-	-	-
11	Koka-12	15.59	19.75	1.56	12.3	11.03	39.81	25.42
12	Zapallo	6.94	15.97	15.04	12.65	15.51	44.52	30.02
13	397	-	0.46	0.29	0.38	-	-	-
14	192054 VI	20.45	20.50	6.75	15.9	-	-	-
15	192054 IV	12.96	16.20	4.55	11.24	18.44	26.24	23.34
16	Bellela	14.28	21.84	9.56	15.23	6.21	39.74	22.97
17	Local check	18.21	-	14.27	6.29	8.49	32.41	20.90
18	Kemb-10	-	-	-	-	10.88	28.32	19.60
19	Lo -323	-	-	-	-	15.97	29.09	22.30
20	Tainunz No 15	-	-	-	-	9.61	24.00	16.80
21	Japon Tresmesino	-	-	-	-	15.16	26.23	20.74

Table 3: Total root yield (t/ha) of combined analysis of participatory evaluation of orange-fleshed sweet potato clones for high provitamin-A.

Sr. No	Treatments	Marketable yield (tone/ha)	Total yield (tone/ha)
1	Zapallo	9.183BC	33.35A
2	Kemb-10	8.063BC	19.60B
3	Lo-323	7.060C	22.53B
4	TIS-8250	16.70A	34.07A
5	192054-IV	11.65ABC	22.34B
6	Bellela	13.50AB	22.98B
7	Tainung No.15	6.713C	16.08B
8	Japon Tresmesino	9.530BC	20.70B
9	Koka-12	1506A	25.42AB
10	Damota	11.98ABC	22.92B
11	Guntutie	8.835ABC	19.52B
12	Local check	11.15ABC	20.45B
13	CV	45.46	33.88
14	LSD	5.734	9.209
15	Grand mean	10.853	23.389

*Treatments followed by the same letter has no significant difference (Duncan's multiple range).

Table 4: Orange-fleshed varieties sweetpotato germplasm having high dry matter, high beta- carotene content shipped to Ethiopia in September 2003.

S.N.	CIP No.	Origin	DM %	Skin color	Flesh color
1	199004.2	CIP breeding line	36	Red	Light orange
2	199005.11	CIP breeding line	26	Pink	Intermediate Orange
3	199015.14	CIP breeding line	25	Yellow	Intermediate Orange
4	199024.1	CIP breeding line	26	Cream	Light Orange
5	199024.2	CIP breeding line	26	Red	Light Orange
6	199026.1	CIP breeding line	26	Red	Light Orange
7	199027.3	CIP breeding line	26	Red	Light Orange
8	99034.1	CIP breeding line	34	Red	Dark Orange
9	199062.1	CIP breeding line	31	Orange	Intermediate Orange
10	440203	Korean Cultivar	28	-	Light Orange
11	440443	Chinese Cultivar	28	Yellow	Light Orange

was obtained from TIS 8250 and Zapallo 34.07 and 30.02t/ha, respectively. These yields were above the best standard check of the year i.e., koka-12 (25.4t/ha). In this trial all varieties yielded above 16.0t/ha, a very encouraging yield, moreover, in a short growing period.

From these, the best clones will be subjected to carotenoid content tests from which the most outstanding will be considered for release.

From the participatory variety trial combined analysis for two years, TIS-8250 and Zapallo (34.07 and 33.35t/ha, respectively) were outstanding (Table 3). Their yields were above the standard checks (koka-12 and Guntute).

In 2003, Awassa Agricultural Research Center introduced 40 virus indexed OFSP clones from CIP-Kenya (Table 4). Out of these 37 clones established well and are being observed.

Alongside these trials, was the sensitisation of farmers about OFSP and their nutritional advantages. In 1987, AARC released two OFSP from the local collection Koka-12 yielded 25.24 t/ha while AJA-I or Guntute yielded 35.35 t/ha. On the basis of this high yield, these varieties were released. Unfortunately, consumers did not adopt them due to their yellow flesh and moist texture. Recently, however, it was realized that high beta-carotinoid content. Due to the awareness created for their richness in Vitamin-A, a total of 97,000 cuttings of these

varieties have been multiplied and distributed on the request of researchers, NGOs and farmers.

A semi-national planning workshop for production and promotion of OFSP was held in the Southern and Oromiya states in March 2002. From this workshop, a project document has been developed and submitted to VITTA.

Future plans

- A workshop to sensitise and identify partners was planned for December 2003 for policy makers and other SHs.
- More awareness activities to create demand of OFSP through radio, TV, workshops, leaflet, field days, etc. have been planned
- Strengthening contact with VITTA networks.
- Multiplication and distribution of released varieties for users.
- Evaluating the recently acquired clones.
- Bringing post harvest & marketing aspects at the fore front

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Evaluation and promotion of orange-fleshed sweetpotato to alleviate Vitamin A deficiency in Orissa and Eastern Uttar Pradesh of India

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Abstract. Sweetpotato is the most important crop next to cereals in Orissa and plays an important role in the agrarian economy of the state. A ready and cheap source of beta-carotene is the orange fleshed sweetpotato, which contains high amounts of beta-carotene, largely responsible for the orange color of the flesh. Vitamin A deficiency can be prevented in children when there is regular intake of 100g of orange fleshed sweetpotatoes everyday. The International Potato center (CIP) had introduced the orange fleshed sweetpotato germplasm CIP 440074 along with other materials like IB-90-10-20, CIP 440127 and CIP-SWA-3 in the Gajapathi, Ganjam districts of Orissa and Gorakhpur district of eastern Uttar Pradesh(UP). CIP-440074 recorded highest yields at all the three locations both in terms of market and fresh root yields. The yield of local varieties at all the three places, when compared with the CIP cultivars was significantly low. Apart from CIP-440074, the cultivar CIP-440127 recorded the second maximum yield at all the three places both in the case of market and fresh root yields. CIP 440074 is very popular in the eastern UP and is ready to be released as a variety in this region because of its high yield and orange color of flesh. High risk of Vitamin A deficiency in the above regions should be reduced by wide cultivation of the orange fleshed sweetpotatoes. The above varieties performed well and should be promoted.

Introduction

Sweetpotato is an important crop in South Asia. Sweetpotato production in the region is about 1.6 million tons on 0.2 million hectares. India accounts for 68% of the total production followed by 27% in Bangladesh and about 5% in Sri Lanka. Sweetpotato is the most important root crop in Bihar and Orissa covering 17,900 ha and 47,900 ha with a production of 170,700 ton and 364,900 ton respectively. It is also an important root crop in Uttar Pradesh covering 30,600 ha with a production of 285,900 ton. It can be grown in poor soils but also performs well in a fertile environment, far exceeding yields of cereal crops. Sweetpotato can be grown with limited land, labour and capital. Early maturing sweetpotato varieties provide higher edible energy per unit area and unit of time than all other major food staples. The tender leaves of sweetpotato vines can be eaten as a vegetable. However, a major use of the leaves, is for animal feeds, particularly for dairy cattle and goats.

Dietary vitamin A deficiency is the world's most common cause of childhood blindness. The world Health Organization (WHO) estimated that as many as 228 million children worldwide are affected subclinically at a severe or moderate level by vitamin A deficiency. About 3 million of these children have some form of vitamin A related eye

disease, ranging from night blindness to irreversible partial or total blindness. Every year, at least 500,000 children become partially or totally blind as a result of this deficiency. Vitamin A deficiency (VAD) causes an estimated 30,000 to 40,000 children in India to go blind each year. Prevalence of vitamin A deficiency rates vary greatly among the states and ranges from 2.2% in Andhra Pradesh to 9.0% in Bihar. Prevalence of VAD is a significant public health problem in India.

A ready and cheap source of beta-carotene is the orange-fleshed sweetpotato, which contains high amounts of beta-carotene (Simonne *et al.*, 1993; Takahata *et al.*, 1993). A regular intake of 100g per day of orange-fleshed sweetpotato roots provides the recommended daily amount of vitamin A for children.

Materials and Methods

Batches of sweetpotato germplasm were introduced in the districts of Ganjam, Gajapathi in Orissa and Gorakhpur in Eastern Uttar Pradesh. Accessions were also acquired from farmers' fields in the above three districts. The

corresponding soil types in the districts are given in Table 1. All the materials were screened at the CIP Regional office farm in New Delhi for over two seasons (Table 2). Seven selection based on fresh root yield were made from these trials.

Evaluation trials. Multi-locational trials at three districts in different agro-ecologies were conducted over two seasons in progressive farmers' fields. Seven selections were grown along with the local variety in the three districts. Based on the results of the multi-locational trials, four selections were made on the basis of fresh root yield. The four selections were evaluated in farmers' fields in the three districts.

Results and Discussion

The highest fresh root yields from the multi-locational trials were recorded in the three districts (Table 3). The four cultivars selected were CIP- 440127, IB-90-10-20, CIP- 440074, CIP-SWA-3. The highest root yields were obtained from Ganjam and Gorakhpur districts. CIP-440074 recorded highest yields at all the

Table 1: Districts and Agro-ecologies of the evaluation trials.

Name of the districts	State	Soil type
Ganjam	Orissa	Sandy-loam soils
Gajapathi	Orissa	Red Sandy-loam soils
Gorakhpur	Uttar Pradesh	River bed loamy soils

Table 2: Performance of the seven local cultivars at the CIP Regional office, New Delhi.

Cultivar	Market root yield (t/ha)	Fresh root yield (t/ha)
CIP-440127	20.7	24.8
IB-90-10-20	17.5	22.9
CIP-440074	22.4	30.1
CIP-SWA-7	16.8	21.2
CIP-SWA-3	19.1	22.4
CIP-SWA-1	12.2	18.2
IB-97-12-7	18.9	21.7
Mean	18.22	23.04
CV	17.86	16.04

Table 3: Performance of 4 cultivars in relation to local variety in various districts.

District/cultivar	Market root yield (t/ha)	Fresh root yield (t/ha)
<i>Ganjam</i>		
CIP-440127	21.2	27.8
IB-90-10-20	16.5	22.3
CIP-440074	26.8	32.3
CIP-SWA-3	21.2	28.4
Local	12.1	17.1
<i>Gajapathi</i>		
CIP-440127	23.4	28.2
IB-90-10-20	20.9	23.2
CIP-440074	24.8	31.0
CIP-SWA-3	19.1	23.2
Local	14.4	16.4
<i>Gorakhpur</i>		
CIP-440127	19.1	30.8
IB-90-10-20	21.4	29.2
CIP-440074	28.3	37.7
CIP-SWA-3	22.1	27.2
Local	16.4	19.1
Mean	20.51	26.26
CV	21.64	22.69

three places both in terms of market and fresh root yields. The maximum fresh root yield was recorded for CIP-440074 at 37.7 t/ha in the Gorakhpur area. The yield of local varieties when compared with the CIP cultivars was significantly low. Apart from CIP-440074, the cultivar CIP-440127 recorded the second maximum yield at all the three places both in the case of market and fresh root yields. IB-90-10-20 recorded high at Gorakhpur area both in terms of market and fresh root yields when compared in Ganjam and Gajapathi districts. CIP-SWA-3 also recorded maximum market and fresh root yields at Gorakhpur district when compared with the local variety. The local varieties yields at the three places were on par with each other ranging from 12.1 t/ha to 19.1 t/ha. The variation in terms of yield was not much significant among the CIP cultivars. CIP- 440074 is more preferred by

farmers in Ganjam, Gajapathi and Gorakhpur districts because of high yield, carotene and the moderate starch content.

Vitamin A deficiency in Orissa Orissa is the largest sweetpotato growing state in India (Table 4). In Orissa, 60% of the population lives below the poverty line and 53% is malnourished. Overall prevalence of Vitamin A deficiency is 0.2% in the country but in Orissa vitamin A deficiency occurs in approximately 0.9 % of the population (Rajalakshmi, 2001). Orange fleshed sweetpotatoes were a potential food substitute to the tribesmen living in the state of Orissa.

Vitamin A deficiency in Gorakhpur (Uttar Pradesh) India. It is estimated that the prevalence of vitamin A deficiency at

Table 4: Area, production and productivity* of sweetpotato in leading states in India.

State	Area (x 1000 ha)	Production (x 1000 mt)	Productivity (t/ha)
Orissa	43.9	361.2	8.2
Bihar	9.9	135.2	13.7
Uttar Pradesh	25.6	302.1	11.8
Assam	8.9	31.0	3.5
Karnataka	3.1	23.3	7.5
Kerala	1.1	11.9	10.8
Tamil Nadu	1.9	32.2	16.9
India	114 (total)	1007 (total)	8.8 (average)

* Source: Indian Horticultural Data base – 2001(National Horticulture Board- Gurgaon, India)

Gorakhpur is 10.97% (Sharma, 1985) and it was most prevalent among children of 3-5 years of age. Gupta (1987) estimated the prevalence of vitamin A deficiency in different child age groups at Gorakhpur, based on hospitalized children (Table 5). Night blindness, conjunctival xerosis, Bitot's spot and active corneal involvement were found in 5.5 %, 15.74 %, 4.72 % and 14.9% of children respectively. Kansal (1997) studied the prevalence of vitamin A deficiency among rural and urban population at Gorakhpur. Overall prevalence of vitamin A deficiency was 6.8 % in children under 5 years of age and it was more prevalent in rural areas (9.3%) than urban areas (3.1%). CIP 440074, which is orange-fleshed, was found to be promising in terms of yield in the Gorakhpur area.

Implications

Farmers use local cultivars, which have poor yields and hence less economic benefits to the resource poor farmers. Introduction of exotic lines with high β -carotene and relatively high dry matter content should improve the economic status of the people in this region in addition to alleviating the vitamin A deficiency. Production of orange fleshed sweetpotatoes should be promoted and integrated with a processing industry ease processing and also to produce high quality sweetpotato products.

Table 5: Distribution of different age groups suffering from vitamin A deficiency at Gorakhpur.

Age group	Children suffering from vitamin A deficiency
2 months-1 year	10%
1-2 years	43.3%
2-3 years	45.8%
3-4 years	61.9%
4-5 years	53.8%
5-6 years	55.3%
Average	40.9%

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Adaptability and acceptability of new orange-fleshed sweetpotato varieties in selected areas of Eastern and Central zones of Tanzania

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Abstract. Orange-fleshed sweetpotato (OFSP) has been earmarked to be among food-based approaches in providing cheap source of beta-carotene a precursor of Vitamin A. Orange coloration intensity in sweetpotato roots correlates positively with the amount of beta-carotene available. In Tanzania, sweetpotato is produced almost entirely for home consumption and majority of popular varieties are either white or yellow-fleshed, which don't qualify to provide enough vitamins to meet the daily requirements. Majority of sweetpotato growers are resource poor with limited access to expensive sources of Vitamin A. Severe deficiency of Vitamin A has been reported to contribute to about 60 percent mortality rates for preschoolers (children aged under 5 years) and pregnant/lactating mothers in South Asia and sub Saharan Africa. In Tanzania, production and utilization of OFSP is limited, hence there was a need to test the adaptability and acceptability of the newly introduced varieties by farmers to ensure wide acceptance hence increased utilization. Twenty improved orange fleshed varieties introduced from CIP in 2001 were evaluated at Kibaha (lowland warm sub-humid) and Hombolo highland warm semi-arid) research stations. Two local checks were included. At harvest, farmers were invited to conduct the acceptability studies so as to capture the consumer-desired qualities. Varieties Tainung-65 (440215) and Japon Tresmesino (420009) produced significantly high yields at both sites. Carrot-

C (local check) gave the least yields. All varieties tested showed mild symptoms of virus disease. Results on farmer's assessment revealed that, among the varieties, Tainung-65, Jonathan, Zapallo and Centennial had generally higher acceptance levels. Others were rejected due to low dry matter, inability to produce enough planting materials especially during the dry season and some due to low yields. Varieties Tainung 65, Jonathan, Zapallo and Centennial have therefore been selected for on-farm testing.

Introduction

Sweetpotato (*Ipomoea batatas*. Lam) is grown throughout Tanzania and is the third most important root and tuber crop after cassava (*Manihot esculenta*) and round potato (*Solanum* spp.). The crop occupies approximately 14 percent of total arable land of the farms surveyed (Kapinga *et al.*, 1995). Consumption of sweetpotato is mostly by boiling; roasting and deep-frying of the roots and the leaves are blanched and used as vegetable.

Vitamin A deficiency (VAD) is the world's most common cause on child blindness (Mukherjee *et al.*, 2002). WHO estimates 228 million children affected sub clinically and 500,000 children become partially/totally blind every year as a result of Vitamin A deficiency. Low *et al.* (2001) reported that, in Sub Saharan Africa (SSA) and Asia, there are severe deficiency of Vitamin A leading to high fatality

rates of 60 percent for preschoolers (children under 5 years of age) and pregnant/lactating mothers. In SSA, estimates of VAD children aged 5 range from 24% to 70% (Harvey and Taylor, 2003).

Promotion of the consumption rate of OFSP at community level is a food-based approach that aims at combating Vitamin A deficiency especially for women and children. Most of sweetpotato growers are resource poor, therefore consume imbalanced diets. Among Vitamin A rich foods, OFSP provides a cheap source of Vitamin A (Low *et al.*, 2001). Orange coloration intensity in sweetpotato root flesh indicates its level of β -carotene (van Jaarsveld, 2003).

Most of sweetpotatoes grown by farmers are white fleshed. Experience indicates that, most of the orange-fleshed sweetpotato varieties currently grown by farmers have low root yields accompanied by low dry matter contents (Mwanga *et al.*, 2003b). High dry matter content is among the major criteria used by farmers in the selection of sweetpotato varieties in Tanzania; especially in the Eastern zone farming communities (Masumba *et al.*, 2003). Therefore there was a need to introduce OFSP varieties adapted to Tanzania conditions and also acceptable to consumers.

Objectives. The following objectives were targeted:

- To introduce and evaluate orange-fleshed varieties.
- Assess consumer acceptability of the introduced orange fleshed varieties.
- Assess the adaptability of the introduced varieties in the two agro-ecologies (lowland warm sub humid and highland warm semi-arid areas).
- To increase the diversity of OFSP to combat Vitamin A deficiency at community level.

Materials and Methods

Tested varieties. Twenty OFSP varieties including the local checks namely Mayai and Carrot-C were used (Table 1).

Research locations. The varieties were evaluated on station for their general performance in terms of their virus reaction, root yield and adaptability. Two different agro-ecologies were identified and used for rapid evaluations of the introduced varieties. These were the lowland warm sub-humid (Kibaha), about 107 meters above sea level with sandy clay loam soils. It is characterized by a weak bimodal pattern of rainfall of an average of 970mm per annum. The second was a highland warm semi-arid (Hombolo) area about 1070 meters above sea level with reddish loamy soils. This area experiences a

Table 1: Twenty orange-fleshed varieties of sweet potato introduced from International Potato Center (CIP), Kenya in 2001.

Variety	CIP number
1. Tainung No. 65	440215
2. Tainung No. 64	440189
3. W-123	440018
4. W-151	440005
5. VSP-3	440287
6. VSP-4	440228
7. Jewel 38	56638
8. Jewel 31	440031
9. TIB	440060
10. Resisto	187017
11. Salyboro	187017
12. Excel	440016
13. BP-SP-2	440293
14. Kandee	440140
15. Zapallo	420027
16. Jonathan	420014
17. Julian	440141
18. CN 317	440090
19. Japon tresmesino	420009
20. Nemanaje	-
21. Centenial	440122

monomodal rainfall pattern with an average rainfall of about 655mm per annum.

Experimental design. A replicated preliminary yield trial was established during the long rains in April 2002 (Kibaha) and January 2003 (Hombolo). This is the common sweetpotato growing season in the respective areas. Plot size was 1.0m x 6.0m and plants spaced at 0.3m as intra-row spacing (i.e., 20 plants per ridge, two/four rows per variety).

Consumer acceptance by farmers. A total of 26 (Eastern zone) and 30 (Central zone) sweetpotato farmers were invited for participatory sweetpotato variety selection at Kibaha and Hombolo research stations, respectively. They were involved in the assessment of the post harvest attributes of the varieties including appearance, taste, mealiness, fibrousness and general acceptability. Clones were assessed by individual farmers using a subjective scale (1=very poor, 2=poor, 3=moderate, 4=good and 5=excellent) (Kapinga *et al.*, 2000). By the use of matrix ranking procedure mean scores were ranked. Farmer opinions on individual clones were computed into frequencies. Scores of the clones were compared using means.

Data collection and analysis. Data collected included plant establishment, virus scores, foliage and root yield (number, weight of the storage roots and dry matter content). A CIP scoring method was adopted and data subjected to the Analysis of Variance (ANOVA) using Mstat-C package.

Results and Discussions

Plant establishment and sweetpotato virus disease reaction. Generally establishment rates at Kibaha were higher with the average of 97.4 % as compared to Hombolo 75.5% (Table 2), probably as a result of semi arid condition the latter location experiences. At Kibaha all the varieties had good establishment rate of above 90.0% except for Julian (440141)

(80.0%). The same variety Julian could not be established at Hombolo because it dried off after planting.

Reaction to sweetpotato virus diseases. Results on severity scores for sweetpotato virus disease ranged between class 2 (mild symptoms on a few plants) and 4 (mild symptoms on many plants, stunting of many plants). Generally, Salyboro and the two local checks (Carrot-C and Mayai) had the lowest scores displaying its mild resistance to the disease (Table 2). The rest of the introductions succumbed to the disease. Kibaha site was however less affected by SPVD than Hombolo. Virus pressure in the region, has slowed down the uptake and promotion of OFSP as noted earlier studies (Kapinga *et al.*, 1995; Kapinga *et al.*, 2003; Mwanga *et al.*, 2003a) and Laurie *et al.*, 2003). CIP however in collaboration with other research organizations has developed new varieties high in dry matter content and beta-carotene with good resistance to sweetpotato virus diseases. These varieties will be introduced in Tanzania soon (Kapinga *et al* 2003, Mwanga *et al* 2003b).

Plant vigour and foliage weight. Most of the varieties had intermediate vigour (class 3). Tainung 65 had the highest plant vigour (class 5 for Hombolo site) followed by the local checks Mayai and Carrot-C (Table 3). Hombolo site gave the lowest yields because of the dry weather as compared to Kibaha site. The amount of rain for the two cropping seasons at Kibaha was abnormally low and erratic.

Root yield and dry matter content. High root yields is among the best criteria that farmers base on in the selection of crop varieties. Average root yields that reported by the Tanzanian Ministry of Agriculture and Food Security are as low as 2.0 t/ha. In this study, at Kibaha site, almost 50% of the total introduced varieties produced higher yields than the local varieties (Table 4). Varieties Salyboro, Japon, Tresmesino, Tainung 65 and

Table 2: Plant establishment of orange fleshed sweet potato varieties and their reaction to virus diseases at Kibaha and Hombolo stations , Tanzania (2002/2003).

Variety/clone	CIP number	Plant establishment (%)		Sweetpotato virus disease evaluation	
		Kibaha	Hombolo	Kibaha	Hombolo
Tainung 64	440189	100.0	78.3	2	4
Jonathan	420014	97.5	76.3	4	4
Salyboro	187017-1	100.0	70.9	2	2
Centenial	440112	92.5	61.6	2	4
W-123	440018	-	73.4	3	4
W-151	440005	92.5		3	4
Zapallo	420027	92.5	79.1	2	4
Jewel 31	440031	100.0	84.0	3	4
VSP-4	440228	97.5	68.9	4	4
Nemanete	-	100.0	86.4	2	4
Kandee	440140	100.0	83.4	3	4
CN 317	440090	97.5	26.5	3	4
Tainung 65	440215	100.0	85.3	2	3
VSP-3	440287	97.5	72.5	4	4
TIB	440060	100.0	82.8	4	4
Jewel 38	56638	100.0	80.8	3	4
Resisto	440001	97.5	65.9	3	3
Excel	440016	100.0	81.0	2	4
Japon Tresmesino	420009	100.0	84.0	2	3
Julian	440141	80.0	-	2	-
Carrot-C	Local check	100.0	73.8	2	2
Mayai	Local check	100.0	95.0	2	2

SPVD scores: 1= No visible symptoms; 5= Completely attacked by virus.

VSP 65 gave higher yields at both sites. Majority of the tested varieties had high dry matter contents (beyond 30% at both sites). Varieties Tainung 64, Nemanete, W-123, CN-317 and Centenial although low yielders gave higher dry matter contents.

Consumer acceptability by farmers: A good number of varieties (55%) tested at both locations were highly accepted by consumers for good taste and other root attributes (Tables 5 and 6). Majority were appreciated for being “dry” as the local ones.

Conclusion and implications

The results showed that OFSP varieties were accepted at both trial sites in Tanzania indicating wide adaptability and acceptability.

Varieties Salyboro, Tainung 65, Japon Tresmeniso, Jonathan, Zapallo, Excell and Kandee are doing well even in other parts of Tanzania, Kenya, South Africa, and Mozambique (Kulembeka *et al.*, 2003; Kapinga *et al.*, 2003; Laurie *et al.*, 2003). These have not been successful in the Lake Victoria Crescent of Uganda because of the high virus pressure (Mwanga *et al.*, 2003). This implies that careful recommendations should be made taking these exceptional cases into consideration. While research continues on breeding to combine multiple resistances to stress factors, most of the introduced varieties can be promoted in low virus pressures. Also breeding programs should target to raise populations using African landraces or improved African germplasm that are already adapted to various stresses. Examples are

Table 3: Plant vigour and foliage weights of the evaluated varieties of orange-fleshed varieties of sweet potato at Kibaha and Hombolo, Tanzania in 2002/3 and 2003/4.

Variety/clone	CIP number	Plant vigour		Foliage weight (t/ha)	
		Kibaha	Hombolo	Kibaha	Hombolo
Tainung 64	440189	3	3	7.7	5.1
Jonathan	420014	3	2	10.0	4.5
Salyboro	187017-1	3	3	11.7	5.0
Centenial	440112	3	1	9.3	1.2
W-123	440018	3	2	-	3.3
W-151	440005	3	—	12.0	-
Zapallo	420027	3	3	11.0	5.0
Jewel 31	440031	3	3	10.7	4.7
VSP-4	440228	3	3	13.0	4.8
Nemanete	-	2	3	6.0	5.5
Kandee	440140	3	2	4.3	3.1
CN 317	440090	2	1	6.7	1.3
Tainung 65	440215	3	5	15.3	5.2
VSP-3	440287	3	3	12.3	4.5
TIB	440060	3	3	6.0	1.9
Jewel 38	56638	3	2	4.0	2.5
Resisto	440001	2	3	3.0	2.0
Excel	440016	3	3	7.7	3.9
Japon Tresmesino	420009	3	3	14.0	4.6
Julian	440141	2	-	2.7	-
Carrot-C	Local check	3	4	9.0	6.1
Mayai	Local check	4	4	11.0	11.5
Mean				8.9	4.3
LSD _{0.05}					3.1

Vigourness: 1= Very poor; 5= Very vigour

successful programs in South Africa, Zambia and Uganda. The sweetpotato breeding and evaluation program in South Africa has been very effective. In South Africa 21 improved cultivars and lines, of which 14 were developed in South Africa, were found to be acceptable to resource-poor farmers and recommended for on-farm testing (Laurie *et al.*, 2003). In Uganda, variety Ejumula (a local landrace) and SPK 004 (an improved variety with an origin in Kenya) have widely been accepted by farmers and processors for their high yields and dry matter contents (Mwanga *et al.*, 2003b).

For this particular study all varieties selected for high root yields, dry matter contents plus consumer acceptance have

been advanced in adaptability studies under diverse agro-ecologies. In these sites multiplication at primary sites have been initiated for the continuous supply of clean healthy planting materials.

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Table 4: Yield performance and dry matter contents of orange-fleshed sweet potato varieties at Kibaha and Hombolo sites, Tanzania (2002-2003).

Variety	CIP number	Root yield (t/ha)						Dry matter content (%)	
		Kibaha			Hombolo			Kibaha (2002)	Hombolo (2003)
		S	L	Total	S	L	Total		
Tainung 64	440189	1.0	7.7	8.7	0.6	2.0	2.6	27.3	35.3*
Jonathan	420014	1.0	10.0	11.0	0.2	1.1	1.3	30.6*	30.7*
Salyboro	187017-1	2.7	11.7	14.4**	1.8	4.0	5.8**	30.7*	30.7*
Centenial	440112	2.0	9.3	11.3**	0.1	0.5	0.6	30.6*	30.6*
W-123	440018	-	-	-	0.1	0.5	0.6	40.8*	40.2*
W-151	440005	3.3	12.0	15.3**	-	-	-	-	-
Zapallo	420027	2.0	11.0	13.0**	0.6	1.9	2.5	25.6	25.7
Jewel 31	440031	2.7	10.7	13.4**	0.8	1.0	1.8	30.5*	30.6*
VSP-4	440228	2.7	13.0	15.7**	0.3	1.6	1.9	28.7	28.6
Nemanete	-	2.0	6.0	8.0	0.4	0.8	1.2	37.5*	37.5*
Kandee	440140	4.7	4.3	9.0	0.6	1.1	1.7	30.7*	28.2
CN 317	440090	5.0	6.7	11.7**	0.3	0.7	1.0	28.2	30.7*
Tainung 65	440215	3.0	15.3	18.3**	0.8	7.8	8.6**	22.8	28.2
VSP-3	440287	3.0	12.3	15.3**	0.3	2.7	3.0**	28.0	28.2
TIB	440060	2.3	6.0	8.3	0.4	2.3	2.7**	30.6*	30.6*
Jewel 38	56638	1.0	4.0	5.0	1.0	2.3	3.3**	23.4	23.6
Resisto	440001	4.0	1.0	5.0	0.5	2.6	3.1**	27.5	27.5
Excel	440016	1.0	7.7	8.7	0.6	3.9	4.5**	42.2*	21.0
Japan Tresmesino	420009	1.7	14.0	15.7**	0.3	3.3	3.6**	27.6	27.5
Julian	440141	2.3	2.7	5.0	-	-	-	36.3*	-
Carrot-C	Local check	1.7	9.0	10.7	-	-	-	34.5*	-
Mayai	Local check	1.3	11.0	12.3*	0.6	0.9	1.5	36.6*	37.9*
Mean		2.4	8.80	11.2	0.5	2.1	2.6	31.0	
CV (%)					28.4	61.6			
LSD _{0.05}					1.0	1.9			

S- Small, L-Large * Selected for high dry matter contents** Selected for high yields.

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Table 5: Farmers assessment of cooked roots of OFSP varieties tested at Kibaha station, Tanzania (2002/03)

Variety	Scores				
	Appearance	Taste	Mealyness	Fibrousness	Overall acceptability
Excel	2.9	3	2.8	4.5	3.2
Jonathan *	3.4	3.3	2.7	3.7	3.7
Jewel *	3.4	3.4	2.8	3.8	3.7
Zapallo*	2.7	3.7	3.1	3.6	3.4
Centenial	3.3	3.4	2.8	3.5	3.2
VSP-4	3.1	2	2	3	2.4
Japon Tresmesino	2.5	3.1	2.5	3.2	3.2
Jewel 38	3.1	2.9	2.5	3.2	2.9
TIB*	2.9	3.3	3.2	3.3	3.3
CN 317	3	2.9	2.8	3.2	3.1
Kandee *	2.6	3.3	4.3	3.7	3.5
Nemanete*	2.9	3.4	3.1	3.7	3.3
Salyboro	2.4	2.2	1.9	2.6	2.3
Tainung 64	3.4	3	2.8	3.1	3.1
VSP 3	2.8	2.3	2	3.3	2.3
Resisto	3	3.4	2.8	3.3	3.1
W-151 *	3.6	3.7	3.4	3.5	3.6
Julian	3.4	2.8	2.5	3.3	3
Tainung 65*	3	3.4	3.3	3.8	3.5
Carrot-C (local)*	3.7	4.5	4.4	4.4	4.4
Mayai*	2.9	2.7	3.2	3.5	3.3

N= 26; Scores: 1= Very bad, 2= Bad, 3= Moderate, 4= Good, 5= Very good

*Selected varieties for further adaptability studies and on-farm evaluation and promotion

Table 6: Farmers' assessment of cooked roots of OFSP varieties tested at Hombolo Station, Central Tanzania (2002/3).

Variety	Scores				
	Appearance	Taste	Mealyness	Fibrousness	Overall acceptability
Excel	3.7	2.9	1.9	2.9	2.8
Jonathan*	3.9	3.9	3.1	4.3	3.8
Jewel	3.3	3.7	2.7	3	3
Zapallo *	3.9	3.7	3.1	4.4	3.6
Centenial*	3.9	3.8	3	3.8	3.8
VSP-4	3.6	3.1	2.8	3.7	3
Japon Tresmesino*	3.6	3.8	2.9	3.7	3.8
W-123*	3	3.4	2.7	3.9	3.3
Jewel 38	3.7	3.2	2.6	3.1	3
TIB*	3.5	3.8	3.1	3.2	3.3
CN 317	3.4	3.2	2.7	3.3	3.2
Kandee*	4.1	3.9	3.1	3.6	3.8
Nemanete	2.8	3.1	3.3	3.4	2.8
Salyboro	3.2	3.4	3.3	3.8	3.2
Tainung 64*	3.7	4	2.6	3.3	3.5
VSP 3*	4	4.1	3.2	4	3.9
Resisto	3.2	3.2	2.8	3.2	3
Tainung 65*	4.2	4.2	3.4	4.4	4.1
Mayai*	2.8	3.4	3.4	3.3	3.3

N= 30; Scores: 1 = Very bad, 2 = Bad, 3 = Moderate, 4 = Good, 5 = Very Good

*Selected varieties for further adaptability studies and on-farm evaluation and promotion

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Genotypic variation among sweetpotato clones for β -carotene and sugar content

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Abstract. An F1 population of parents and half-sibs was replicated in field plantings to generate roots to assess levels of β -carotene, sucrose, maltose, and fructose. DNA was also extracted from each genotype and used to generate AFLP molecular markers. The intent was to identify trait-linked AFLP molecular markers. Genotypes were grouped into phenotypic classes based on their standard deviations from the mean. Association parameters between three classes of each respective sugar and molecular marker profiles were made. Discriminant analysis was found to be a useful tool in building progeny selection models in breeding trials.

Introduction

The importance of the nutritive value of the sweetpotato as human food and animal feed has been well documented by Woolfe (1992). Rubatzky and Yamaguchi (1997) state that as a food, the roots may be roasted, baked, fried or prepared in various combination dishes, providing a rich source of carbohydrates and Pro-vitamin A. Pro-vitamin A or β -carotene and sugar content have been found to be important consumer traits for various markets (Woolfe, 1992).

Recent studies on root sugar and β -carotene content have focused on physiological assessment and little on breeding strategies (Bushway, 1986; Picha, 1987; Lu and Sheng, 1990; Katayama *et al.*, 1996; K'Osambo *et al.*, 1998 and Labonte *et al.*, 2000). According to Picha (1987) carbohydrates constitute most of the dry

matter in sweetpotatoes and these carbohydrates exist in the form of starch and sugars. Sucrose, glucose and fructose are the main sugars in raw sweetpotatoes and sweeter baked sweetpotatoes are usually more acceptable to consumers. Picha (1985) also developed reliable HPLC procedures for quantitative analysis of sugars in raw and baked sweetpotatoes. Other methods that have been used for sugar determination include refractive index (Walter, 1992) and near infrared transmittance (Lu and Sheng, 1990; Katayama *et al.*, 1996). Bushway (1986) and Simonne *et al.* (1993) have used HPLC for determination of β -carotene content. However this methodology is tedious and Takahata *et al.* (1993) have documented a quicker method that links β -carotene content and the intensity of the orange flesh color of the sweetpotato. β -carotene has been associated with prevention of night blindness in children and orange fleshed sweetpotato cultivars being low input crops are therefore attractive sources for β -carotene for low income societies.

Most of the breeding programmes for cultivars with high β -carotene have used a classical approach of mass selection. Cultivars that have been developed using this method include 'Jewel' and 'Beauregard'. However, genetic advance in breeding sweetpotatoes with desirable traits is slow and resource consuming.

Hall and Phatak (1993) have reported that the low success in interspecific crosses has precluded the use of genetically related species in sweetpotato improvement. The

hexaploid, self-incompatibility and heterozygous nature of the sweetpotato make inheritance studies very complicated. This genetic condition greatly affects breeding and selection for quantitative traits by slowing down progress in genetic advance within sweetpotato breeding programmes. However the high level of heterozygosity and wide diversity in the germplasm of cultivated sweetpotatoes have also been valuable sources of favorable genes for traits that need to be incorporated through appropriately designed breeding and selection methodologies. Jones (1965, 1986) has proposed breeding methods for many quantitative traits; however, reports on breeding methods that incorporate molecular marker approaches for organoleptic traits are uncommon. Such molecular techniques that would affect interspecific gene transfer could greatly improve quantitative breeding programs (Hall and Phatak, 1993).

Molecular marker assisted selection in sweetpotatoes began with the use of bulked segregant analysis (BSA) (Michelmore *et al.*, 1991) by Ukoskit *et al.* (1997). In their study, Ukoskit *et al.* (1997) identified a primer that could be used to detect linkage between DNA markers and the root-knot nematode resistance gene. The biggest drawback of BSA is the need for new DNA bulks from a homozygous pure F₂ population for every loci targeted. In addition we are not assured of detecting differences between bulks. These hurdles spurred us on to seek alternative approaches to marker assisted selection for sweetpotato improvement. One such approach is the use of a multivariate statistical technique, namely discriminant analysis to associate molecular markers with quantitative traits. Due to the sparsely saturated genome maps in sweetpotato, we seek to develop a method that does not require *a priori* genetic maps and also one that is capable of analyzing multiple traits or variables simultaneously. The multiple variables or molecular markers in our case were generated by AFLP. Discriminant analysis (DA) is a multivariate statistical technique that can identify

differences among groups of individuals (or treatments) and improve the understanding of relationships among the variables measured within those groups (Cruz-Castillo *et al.*, 1994). DA determines how best to separate or discriminate two or more groups of individuals, given quantitative measurements of several individuals, through simultaneous analysis of several variables (Rencher, 1992). DA finds linear functions of variables that maximally separate two or more groups of individuals while keeping variation within groups as small as possible. DA may be used when it is important to separate known groups or *a priori* groupings, and to identify major sources of difference between groups. Such groups may be determined through a statistical procedure like molecular marker profiling or through cluster analysis techniques. The discriminant analysis will therefore provide information on the discriminatory power of each variable or marker thus determining whether a particular set of variables or markers is useful in separating previously delineated groups (Rojas *et al.*, 2000). We propose to use AFLP and discriminant analyses in a marker-trait association study with the main objective of identifying trait-linked AFLP molecular markers for sugar and β -carotene content.

Materials and Methods

Planting material. An F₁ population of parents and half-sibs that consisted of 45 clones was used as source material. Maternal parental clones used to obtain the open pollinated F₁ half-sibs were 'Beauregard', 'Excel', '94-96', '86-110', '86-33' and '96-117'. F₁ 'Beauregard' progeny were coded as 'BX' while 'Excel' F₁ progeny were coded as 'EL'. The rest of the F₁ progeny were given the codes '96', '110', '33' and '117' to reflect parentage. Field trials were conducted during summer at the Sweetpotato Research Station (Chase), Louisiana in 2001. Each experiment was laid out as a randomized complete block trial with 3 blocks. Each plot consisted of 5 plants with an inter-row spacing of 60cm and

within row spacing of 30cm. Field management followed commercial sweetpotato cultural practices recommended by Boudreaux (1994). The crop was harvested after four months and four to five roots from all the plants in a plot were combined for post-harvest laboratory analysis. The roots were cured at 29°C and 90 to 98% relative humidity for about 10 days. Thereafter the roots were stored at 15°C and 90% relative humidity.

DNA analysis. DNA extraction and DNA analysis using AFLP were done as described by (Mcharo et al, 2003). Young leaves were harvested and stored at -40°C until needed. Total DNA was isolated from 100mg of fresh leaf tissue using the Genelute plant genome kit (Sigma-Aldrich Inc., St. Louis, Mo). The DNA samples were amplified in a three step process using a GeneAmp PCR system 9600 thermocycler (Perkin Elmer, Fulerton, CA) using techniques adapted from Vos et al (1995). Four primer pairs were used for selective amplification.

Sugar and β -carotene analyses. Analyses of sugar and β -carotene content were done on raw roots stored for 4 to 10 weeks after curing, during which sugar content changes were minimal (Picha, 1987). Sugar content was assayed as described by Picha (1987). Unpeeled roots were halved longitudinally and uniformly grated over the entire surface to a depth of about 3 mm. The grated tissue from each of the 4 roots per replication was combined and 10.0g was homogenized in 80% ethanol for 1 min at high speed using a Brinkman homogenizer (Brinkman Instruments, Westbury, NY). The resulting slurry was immediately boiled for 15 min, cooled, and filtered through Whatman #4 paper. The residue and original container were washed with additional 80% ethanol and the filtrate was made to a final volume of 100ml. Sugar content of the filtrate was determined by high performance liquid chromatography (HPLC) as described by Picha (1985).

Hunter color values (Hunter, 1958) measurements were taken on the flesh of representative cured roots from each plot using a Minolta spectrophotometer cm 3500d (Minolta Co., Osaka, Japan). This color system is based on *L*, *a* and *b* measurements where *L*=lightness, *a*=green-red scale, *b*=blue-yellow scale and intensity. This method measures color by using a positive and negative number scale. For the color value *a*, a positive value is perceived as red, a negative value as green. For the color value *b*, a positive value is perceived as yellow, a negative value as blue. Lightness (*L*) is measured on a scale of 0-100 where 0 = black and 100 = white. Flesh color measurements were taken by measuring the cross-section of the interior of the root.

Statistical analysis. Step discriminant analysis using the STEPDISC procedure (SAS, 2001) was used to select the most informative markers from the original set of markers. The forward selection options in STEPDISC was used to select markers to be included in the classification model. A stop level for the number of markers desired to achieve at least 85% prediction accuracy was imposed to choose the most discriminating markers (SAS, 1999). Wilk's lambda was used as the criterion to determine the classification efficiency with the entry of each marker. The selected markers were then used in a discriminant analysis, DISCRIM option (SAS, 2001), to develop and validate a phenotypic group prediction model and to predict group membership of the test genotypes. The categorical nature of the data could not allow assumption of normal distribution to be made hence a non-parametric method; the k-nearest neighbor method (Rosenblatt, 1956) was used to estimate the group specific densities that produce a classification criterion. The performance of the discriminant criterion was evaluated by group specific error count estimates during cross-validation. This estimator gives the proportion of misclassified observations in each group.

Results and Discussion

Sugar content. Table 1 outlines the sugar content of the various clones studied. Phenotypic grouping of the clones for all sugars was based on the number of standard deviations from the mean. Group 1 contained clones that were equal to or less than negative two standard deviations from the mean. Clones in group 2 were within negative one and positive one standard deviation from the mean while group 3 had consisted of clones at positive two standard deviations or greater. Fructose content ranged from 3.58 ug/20ul of solution in the clone 110-1 to 18.35ug/20ul of solution in BX-8. The same clones had the lowest and highest glucose contents respectively with 110-1 having 6.41ug/20ul and BX-8 containing 30.03 ug/20ul. Clone 110-11 recorded the highest sucrose content at 60.13ug/20ul however the same clone had low scores for fructose (9.31ug/20ul) and glucose (13.31ug/20ul). Labonte *et al.* (2000) observed similar sugar content trends in other cultivars. Clone 110-1 had a very high sucrose content while clone BX-8 contained low levels of sucrose. The lowest sucrose content was recorded in clone 117-9 (17.19ug/20ul).

β -carotene content. Investigations by Takahata *et al.* (1993), Ameny and Wilson (1997) and Hagenimana *et al.* (1998) revealed negligible levels of β -carotene in non-orange cultivars. Takahata *et al.* (1993) studied the relationship between β -carotene content and Hunter color values in sweetpotato cultivars. They found that color value a^* had the highest correlation coefficient (0.891) with β -carotene and concluded that the color value a^* could be used in rapidly estimating the β -carotene content in breeding programs. The results for the Hunter color value a^* are presented in Table 2. The phenotypic grouping was based on the clear demarcation between white, cream-yellow and orange flesh color of clones from visual observation and as represented by the Hunter color value a^* . Group1 clones had a white flesh color; group 2 clones had various shades of cream-yellow flesh color

while group 3 clones were orange. Clone 96-9 had the lowest a^* value (-0.10) and a concomitant high L^* value (data not shown). This clone had a white flesh color and was not expected to contain any determinable β -carotene quantities. Clone 117-7 had a deep orange color and recorded the highest a^* value (36.80); however it's L^* value was not as high as that of 96-6. A high L^* value indicates an increasing lightness in the color hence a lower level of β -carotene content.

Discriminant analysis. Discriminant analysis (Table 3) elucidated informative markers that could be used for classification of a genotype of unknown grouping. The numerical value for each marker name indicates its molecular weight in base pairs. We noted that markers *cag60* and *cag203* were important in describing variation for both fructose and glucose. However the same markers were not important in explaining variation for sucrose. Discriminant analysis selected marker *cag253* (Table 3) as the most informative in describing variation for β -carotene content within the samples studied. Table 3 also shows the total number of markers selected to build a predictive model for genotype classification purposes. The objective of selecting the markers was to build models that contained as few markers as possible without compromising on their phenotypic group prediction accuracy. When tested by cross-validation the models achieved a prediction accuracy of at least 85% for fructose and 92% for glucose. β -carotene needed fewer markers for the discriminant model than the sugars.

Conclusion

Our results indicate the possibility of using molecular markers to predict phenotypic grouping of new genotypes of unknown nutrient composition. We found promising results through the use of the discriminant analysis technique for quick selection during the early stages of sweetpotato breeding. A second year of data is currently being

Table 1: Fructose, glucose and sucrose content and resultant phenotypic classification of sweetpotato clones from an F₁ polycross of 'Beauregard', 'Excel', '94-96', '86-33', '86-33' and '96-117'.

Clone name	Fructose		Glucose		Sucrose	
	mg/g	Group	mg/g	Group	mg/g	Group
110-1	2.0	1	3.0	1	29.5	3
110-11	4.5	2	6.5	2	30.0	3
110-12	3.5	2	5.5	1	16.5	2
110-4	4.5	2	6.5	2	16.0	2
110-5	8.0	3	12.0	2	19.5	2
110-6	2.5	1	4.5	1	21.5	2
110-9	8.0	3	13.5	3	14.5	2
117-1	3.5	2	7.0	2	24.5	2
117-10	5.0	2	10.0	2	16.0	2
117-3	8.5	3	15.5	3	17.5	2
117-5	2.0	1	3.5	1	17.5	2
117-6	4.5	2	10.0	2	16.0	2
117-7	4.0	2	7.5	2	19.5	2
117-8	4.5	2	9.5	2	17.0	2
117-9	8.5	3	14.5	3	8.5	1
117p	4.5	2	7.5	2	22.0	2
33-1	7.0	2	12.0	2	18.0	2
33-10	4.0	2	6.5	2	27.5	3
33-11	3.0	1	5.0	1	23.5	2
33-3	9.5	3	15.0	3	20.0	2
33-7	6.0	2	10.5	2	16.0	2
33-8	8.5	3	14.6	3	23.0	2
33-9	8.5	3	13.5	3	17.5	2
96-10	5.0	2	11.5	2	29.5	3
96-11	5.5	2	7.5	2	30.0	3
96-2	3.5	2	6.5	2	23.5	2
96-4	5.5	2	10.5	2	25.5	3
96-5	4.0	2	7.5	2	22.0	2
96-7	7.0	2	12.5	2	23.5	2
96-8	2.0	1	3.5	1	27.5	3
96-9	5.5	2	10.0	2	11.0	1
96p	7.0	2	11.0	2	23.0	2
BX-1	8.5	3	13.5	3	10.0	1
BX-16	7.0	2	12.0	2	21.0	2
BX-2	7.0	2	11.0	2	16.5	2
BX-21	3.0	1	5.0	1	15.5	2
BX-5	7.0	2	11.0	2	22.5	2
BX-6	6.5	2	11.5	2	15.0	2
BX-8	9.0	3	15.0	3	12.5	1
BXp	7.0	2	12.0	2	11.5	1
EL-11	6.5	2	15.5	3	16.0	2
EL-4	2.5	1	4.5	1	14.5	3
EL-5	7.5	2	15.0	3	9.5	1
EL-7	9.0	3	13.5	3	16.0	2
EL-8	3.5	1	6.0	1	20.5	2

Clones followed by the letter 'p' are parental clones.

Table 2: Hunter color value a* and phenotypic classification for β -carotene content of sweetpotato clones from an F₁ polycross of 'Beauregard', 'Excel', '94-96', '86-33', '86-33' and '96-117'.

Clone name	Color value a*	Phenotypic group
110-1	29.47	3
110-11	31.79	3
110-12	15.63	2
110-4	30.92	3
110-5	31.22	3
110-6	30.46	3
110-9	24.45	3
117p	36.51	3
117-1	33.47	3
117-10	32.21	3
117-3	30.50	3
117-5	33.77	3
117-6	28.73	3
117-7	36.80	3
117-8	18.96	2
117-9	2.13	1
33-1	21.57	3
33-10	3.19	1
33-3	33.48	3
33-7	28.01	3
33-8	25.84	3
96-10	2.27	1
96-11	30.25	3
96-2	9.67	1
96-4	22.83	3
96-7	17.45	2
96-8	31.46	3
96-9	-0.10	1
96p	31.40	3
BX-1	5.00	1
BX-16	13.43	2
BX-2	24.20	3
BX-5	31.18	3
BX-8	33.96	3
BXp	27.99	3
EL-11	11.92	1
EL-4	33.09	3
EL-5	0.89	1
EL-7	30.63	3
EL-8	14.90	2

Clones followed by the letter 'p' are parental clones.

Table 3: Four most informative markers for sugar content and β -carotene in sweetpotato.

Trait		Total markers selected	4 most important markers selected	Wilk's Lambda	Pr < Lambda
Sugars	Fructose	14	cag203	0.72	0.0023
			cag60	0.50	<0.0001
			cag95	0.35	<0.0001
			cag147	0.28	<0.0001
	Glucose	13	cag240	0.74	0.004
			cag203	0.57	0.0004
			cag60	0.43	<0.0001
			cag192	0.33	<0.0001
	Sucrose	11	cag206	0.71	0.0018
			cag122	0.52	<0.0001
			cag91	0.37	<0.0001
			cag119	0.27	<0.0001
β -carotene		10	cag253	0.68	0.0007
			cag91	0.52	<0.0001
			cag94	0.40	<0.0001
			cag242	0.31	<0.0001

Table 4: Error count estimates from cross-validation using nearest neighbor for various traits in sweetpotato.

	Phenotypic group			Total
	1	2	3	
Fructose	0.33	0.12	0.00	0.15
Glucose	0.14	0.09	0.00	0.08
Sucrose	0.17	0.00	0.13	0.10
β -carotene	0.12	0.20	0.04	0.12

analyzed to more fully document our preliminary findings.

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Potential of cassava and sweetpotato leaves to contribute to the Vitamin A requirements

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Abstract. Cooked green leafy vegetables constitute a regular relish in most households of Tanzania, usually served as a side dish for the starchy based staples. Provitamin A carotenoids from these vegetables are major dietary sources of vitamin A in Tanzania. Cassava and sweetpotato are widely grown in Tanzania including the semi-arid areas due to their tolerance to harsh weather conditions. Besides caloric density provided by these tubers to the diet, their leaves also contribute to the vitamin A requirements of populations in production areas. In this study five sundried green leafy vegetables including leaves of cassava and sweetpotato were cooked without oil, with sunflower oil or with red palm oil. The total amount and *in vitro* accessibility of α -carotene and β -carotene from a portion (100g) of vegetable relish was determined. The *in vitro* method used simulated the digestion process in the gastrointestinal tract. Carotenoids released after digestion were quantified using high performance liquid chromatography. The total amount of β -carotene varied between 1211 and 3659 mg/100g among the five vegetable sources studied. From green leaves cooked without oil, 8-29% of the β -carotene content became accessible after *in vitro* digestion and 39-94% from leaves cooked with sunflower or red palm oil. Adding red palm oil instead of sunflower oil resulted in about twice as much accessible β -carotene, due to high accessibility of its β -carotene content. The red palm oil contributed also a considerable amount of α -carotene. The results showed

that by eating vegetable relishes with added oil daily, it should be possible to provide the recommended intake amount of vitamin A.

Introduction

Plants and animals are two major dietary sources of vitamin A in humans. Vitamin A from animal sources is in a preformed form and therefore readily available for utilization whereas that from plant sources is in the form of provitamin A carotenoids which have to be converted to the active form of vitamin A (retinol) and its derivatives in the gut before being utilized (Booth *et al.*, 1992). This implies that, of the two major dietary sources of vitamin A, animal sources would be most preferred in terms of efficacy of vitamin A supply to humans. However, in most developing countries animal sources of vitamin A are scarce, expensive and beyond the reach of the majority due to socio-economic constraints. Thus provitamin A carotenoids from vegetables and fruits remain the major dietary source of vitamin A in these countries. In Tanzania various types of leafy vegetables including sweetpotato (*Ipomoea batatas*) and cassava (*Manihot esculenta*), are widely consumed and constitute a regular relish in many rural households.

Increased consumption of carotene rich vegetables and fruits has for a long time been recommended as the most appropriate and sustainable solution for improving vitamin A status of populations in low-income countries due to their high carotene contents. However,

it is now known that the ability of provitamin A carotenoids from leafy vegetables to improve vitamin A status is limited by their low bioavailability (de Pee *et al.*, 1995 and 1998; Castenmiller *et al.*, 1999). Bioavailability is defined as the efficiency with which provitamin A carotenoids are absorbed and converted into vitamin A in the body. Thus to maximize the benefit of provitamin A containing foods, strategies to increase the dietary intake of these foods should also include measures to enhance carotenoid bioavailability.

This paper discusses some processing and preparation methods, which have been found to enhance the bioavailability of provitamin A carotenoids from plant sources. Results from our research study on the *in vitro* accessibility of carotenes in leafy vegetables cooked without and with sunflower or red palm oil and their estimated contribution to the vitamin A requirements support available information.

The objective of our study was to determine α -carotene and β -carotene content and the *in vitro* accessibility in five types of green leafy vegetables commonly used in Tanzania and cooked with either sunflower or red palm oil.

Materials and Methods

The study emulated the traditional method of vegetable processing commonly practiced in semi-arid areas of central Tanzania. It involves sun drying of fresh vegetables, a method commonly used to preserve vegetables for off-season consumption. The dry vegetables were cooked into a vegetable relish using a traditional recipe without and with oil (red palm oil or sunflower oil). Cooked vegetable relish samples were analyzed for the bioaccessibility (amount released from the vegetables after digestion and available for absorption in the gut) of their carotenes using an *in vitro* digestion method. The contribution of one portion of vegetable relish to the recommended daily intake (RDI) was obtained by calculation.

Five different types of freshly harvested green leafy vegetables were purchased from markets in Dar es Salaam. They included the leaves of amaranth (*Amaranthus* spp), cow pea (*Vigna* spp), sweetpotato (*Ipomoea batatas*), pumpkin (*Cucurbita moschata*) and cassava (*Manihot esculenta*).

The sunflower oil (Zeta) used was purchased in a supermarket and the red palm oil (Carotino, Malaysia) was taken from a large stock, which was to be used in a dietary intervention study with pregnant women in Tanzania (Lietz *et al.*, 2000).

Sample preparation. After blanching in boiling water for 2-3 minutes, all the leaves were sundried in open sunlight. A portion of fresh leaves from each vegetable were blanched and then kept frozen as a reference sample. Samples were transported under cold conditions and kept in a freezer (-20 °C) before analysis. The reference sample was freeze-dried before determination of total content of α - and β -carotene.

Each type of the sundried leaves was divided into three equal portions (~10g dry weight) and cooked in the laboratory according to the traditional recipe. The leaves were soaked in tap water (1:9) for about 5 min and cooked with a small amount (~1g) of table salt for 15 min. In two of the samples sunflower oil or red palm oil was added at the end of the cooking time. The ratio of sundried vegetable leaves to oil was about 1:1, on a dry weight basis. Caution was taken to avoid excessive boiling after addition of oil. Cooked samples were kept frozen at -20 °C and later freeze-dried before analysis. For comparison of results one portion of vegetable relish was standardised to 100 g, which included 10 g of sundried green leaves, water and no oil or 10 g of sunflower oil or red palm oil.

Determination of oil content in prepared vegetable relish. The oil content in the vegetables cooked with either sunflower oil or red palm oil was determined by using Soxhlet extraction (AOAC 963.15) AOAC, 1990). Extraction was performed with

petroleum ether (B.P. 40-60°C) (Merck, Darmstadt, Germany).

Determination of carotene content in vegetables. Carotenoid extractions were carried out according to a method described by Pettersson and Jonsson (1990). High Performance Liquid Chromatography (HPLC) grade solvents of methyl-t-butyl ether, methanol, acetone and petroleum ether (B.P. 40-60°C) (Merck) were used. Other chemicals used were 95% ethanol (Kemetyl AB, Stockholm, Sweden) and analytical grade sodium chloride (Merck).

The freeze-dried vegetable relish was ground in a blender for about 30 seconds. About 0.5 g of the finely ground sample (in duplicate) was accurately weighed into a flask, reconstituted with 10 ml of distilled water and allowed to stand for 5-10 min. In one of the duplicates 100 µl of an internal standard (200 µg trans-β-apo-8-carotenal/ml) (Sigma Chemicals A-9956, St Louise, MO, USA) was added. The extraction was repeatedly carried out by moderate shaking for 5 min with equal amounts (20 ml) of acetone and ethanol containing 0.1 % (w/v) butylated hydroxytoluene (BHT) (Sigma Chemicals), until the residue was colourless. The extracts were decanted into a separatory funnel containing 20 ml of petroleum ether and 20 ml of 25 % (w/v) NaCl solution. After transferring the carotenes to petroleum ether by gently swirling the separatory funnel, the lower layer was drawn off and washed repeatedly with 20 ml of petroleum ether until the extract was colourless. The pooled extracts were evaporated under nitrogen in a rotary vacuum evaporator at 35 °C. The residue was dissolved in 10 µl of mobile phase solvent and filtered through a 0.45 µm pore size cellulose membrane filter (Sartorius Filtration AB, Sundbyberg, Sweden) before HPLC analysis.

Due to the risk of oxidation and formation of isomers during sample preparation, the extraction was performed at dimmed light and room temperature.

Determination of in vitro accessibility of carotenes. The in vitro digestion procedure developed by Hedrén *et al.* (2002), which simulates digestion in the gastrointestinal tract, was used to determine the bioaccessibility of carotenes in the vegetable relishes. Briefly, the freeze-dried vegetable relish was homogenized and reconstituted with distilled water. Digestion was carried out by acidifying the sample (pH 2), followed by treatment with porcine pepsin solution and incubation at 37°C in a shaking water bath for one hour. The pH was adjusted to 7.5 and a pancreatin and bile salt solution was added. The sample was further incubated for 30 min. The digesta was centrifuged and the aqueous fraction was extracted with petroleum ether that was evaporated to dryness. The residue was dissolved in 5 or 10 ml of mobile phase solvent and filtered through a 0.45 µm pore size cellulose membrane filter before a reverse phase HPLC analysis.

HPLC determination of provitamin A carotenoids. Trans-β-apo-8-carotenal was employed as internal standard and all-trans-β-carotene (Sigma Chemicals C-9750) was used as an external standard. The concentration of β-carotene standard working solution was confirmed using a spectrophotometer, Hitachi U-1100 (Hitachi Instruments, San Jose, USA), and using the extinction coefficient value for β-carotene in hexane. The provitamin A carotenoids, α- and β- carotene, were determined by isocratic reversed phase HPLC using methyl-t-butyl ether: methanol: water (56:40:4) as mobile phase. The HPLC system comprised a Waters 600 dual piston solvent delivery pump (Waters, Söllerntuna, Sweden) connected to a Waters 996 UV-visible photodiode array detector (Waters) and equipped with a C₃₀ polymeric column (YMC Inc., Wilmington, NC, USA). The C₃₀ ligands are bonded on high silica particles (5 µm) in a stainless steel 250 mm column (4.8 mm i.d.), allowing for phase loading and polarity optimised for

separation of both polar and non-polar carotenoids and their isomers. Millenium 2010 software (Waters) was used to acquire, store and process spectra and chromatographic data. Absorption spectra of the carotenoids were recorded between 250-500 nm at the rate of 0.5 spectra per second and the resolution of 2.4 nm. The flow rate was 1 ml/min and injections were made with a 20 µl loop.

Statistical analyses. Differences in mean values of total β-carotene content in cooked vegetable relishes were tested by analysis of variance (ANOVA). Determination of the significance of differences ($p < 0.05$) among samples cooked without oil, with sunflower oil or red palm oil were obtained by Tukey's HSD multiple rank test.

Results and Discussion

This study has shown that green leafy vegetables studied are good sources of β-carotene with the amount in blanched leaves ranging from 399 to 664 µg/g DM (Table 1). Small proportions of α-carotene amounting to 17±5.2 and 31±2.3 µg/g DM were detected in blanched leaves of amaranth and sweetpotato respectively. Sundrying of vegetables resulted in a wide range of loss of the β-carotene content in the different vegetables (Table 1). However, sweetpotato and cassava leaves retained higher amounts

(62% and 63%) of β-carotene than other vegetables. After sundrying no α-carotene was detected in any of the green leaves. The average amount of total β-carotene from one portion (100g) of the vegetable relishes are shown in Table 2 and varied between 1211 and 3649 µg when cooked without oil. The oil content in the vegetable relishes cooked with either sunflower oil or red palm oil ranged from 47 to 52 %. The total amount of α- and β-carotene in the red palm oil was 107±6.2 and 125±5.2 µg/g oil, respectively.

Of the amount of β-carotene retained, only 8-29 % is available for absorption after cooking without adding oil as measured by an *in vitro* digestion method, which measures the maximum amount of carotenes possible for absorption (Table 3). Adding sunflower oil in the preparation resulted in a manifold increase of the accessibility due to the reasons provided in the section on *in vitro* accessibility of carotene from cooked vegetables ahead. Red palm oil that contains both α- and β-carotene further increased the amount of accessible carotenes to the vegetable relishes when added in the preparation. Calculations made showed that green leafy vegetables cooked without oil may only constitute from 12 to 47% of an individual's daily need of vitamin A, whereas green leaves cooked with either sunflower oil or red palm oil may provide enough daily retinol (Table 4). These findings may have

Table 1: The total amount of A- and β-carotene in green leaves before and after sundrying, (µg/g DM)¹.

Green leaves	Blanched		Blanched and sundried ²	Losses of β-carotene during sundrying ²
	β-carotene	α- carotene		(%)
Amaranth	664±7.8	17±5.2	287±18	57
Cowpea	622±14	Trace	148±1.3	76
Sweet potato	592±9.8	31±2.3	365±7.7	38
Pumpkin	590±21	Trace	121±3.9	79
Cassava	399±15	Trace	250±2.8	37

¹ Mean ± SD in duplicate samples.

² α- carotene was only detected in blanched green leaves.

Table 2: The total α - and β -carotene content in each portion of vegetable relish ($\mu\text{g}/100\text{g}$)¹.

Green leaves	Without oil ²	With sunflower oil ²	With red palm oil	
	(β -carotene)	(β -carotene)	(β -carotene)	(α - carotene)
Amaranth	2851 $\pm$ 17 ^a	2974 $\pm$ 39 ^a	4193 $\pm$ 51 ^b	1491 $\pm$ 73
Cowpea	1475 $\pm$ 13 ^a	1418 $\pm$ 61 ^a	2836 $\pm$ 11 ^b	1196 $\pm$ 5.8
Sweet potato	3659 $\pm$ 106 ^a	4008 $\pm$ 90 ^a	5443 $\pm$ 296 ^b	1480 $\pm$ 76
Pumpkin	1211 $\pm$ 39 ^a	1526 $\pm$ 36 ^b	3067 $\pm$ 17 ^c	1203 $\pm$ 16
Cassava	2233 $\pm$ 71 ^a	2728 $\pm$ 7.0 ^b	4637 $\pm$ 47 ^c	1427 $\pm$ 8.0

¹ Mean $\pm$ SD in duplicate samples. Equivalent to 10 g dry weight of vegetable leaves.

² No α - carotene was detected in relishes cooked without oil or with sunflower oil.

^{abc} Values on the same row not sharing the same superscript were significantly different ($p < 0.05$).

Table 3: The in vitro accessibility of α - and β -carotene in each portion of vegetable relish¹.

Green leaves	without oil ²		with sunflower oil ²		with red palm oil			
	β -carotene		β -carotene		α - carotene		β -carotene	
	(μg)	(%) ³	(μg)	(%) ³	(μg)	(%) ³	(μg)	(%) ³
amaranth	512 $\pm$ 29	18	1724 $\pm$ 137	58	1212 $\pm$ 72	86	2861 $\pm$ 250	68
cowpea	426 $\pm$ 31	29	1267 $\pm$ 73	94	1120 $\pm$ 33	94	2357 $\pm$ 81	83
Sweet potato	316 $\pm$ 37	9	1559 $\pm$ 238	39	1343 $\pm$ 15	90	3240 $\pm$ 246	61
Pumpkin	125 $\pm$ 35	10	969 $\pm$ 146	64	1067 $\pm$ 12	88	2468 $\pm$ 155	81
Cassava	178 $\pm$ 15	8	1284 $\pm$ 29	47	793 $\pm$ 65	56	2340 $\pm$ 201	51

¹ Mean $\pm$ SD in two duplicate samples. Equivalent to 10 g dry weight of the vegetable leaves.

² No α - carotene was detected in relishes cooked without oil or with sunflower oil.

³ Percentage in vitro accessible α - and β -carotene, respectively.

Table 4: The percentage contribution of retinol equivalents (RE) to the recommended safe intake level¹ by one portion of vegetable relish².

Green leaves	Without oil	With sunflower oil	With red palm oil
	(%)	(%)	(%)
Amaranth	47	157	316
Cowpea	39	115	265
Sweet potato	29	143	356
Pumpkin	12	89	273
Cassava	16	116	249

¹ Recommended safe intake level of vitamin A in populations in developing countries, 550 μg RE/day (WHO/UNICEF, 1995)

² Assuming 100 % absorption of the in vitro accessible α - and β -carotene and 25 and 50 % conversion to retinol in mucosa, respectively.

major implications for the design of intervention studies that use a dietary approach to combat vitamin A deficiency in developing countries.

Effect of drying on carotene contents of vegetable. Green leafy vegetables are available throughout the year for most people in Tanzania. However, during dry season in semi-arid areas people mainly rely on leaves dried in open sunlight. Exposure to light and oxygen are known to have an impact on the carotenoids through oxidation and isomerization (Thane & Reddy 1997; Mosha *et al.*, 1997). Maeda and Salunkhe (1981) obtained substantial losses of carotenes (60-94 %) when green leaves of sweetpotato, cassava and cowpea were sundried without blanching. In this study leaves meant for cooking were blanched prior to sundrying, in order to inactivate the enzyme peroxidase and thereby prevent losses of carotenes from degradation to some extent (Negi and Roy, 2000). This resulted in losses between 37 and 79 % of the β -carotene content that is less compared with what was reported by Maeda and Salunkhe (1981). An alternative to drying in open sunlight is the solar drying technology, whereby products are protected from light and therefore retain more carotenes (Maeda and Salunkhe, 1981; Negi and Roy, 2000; Mulokozi *et al.*, 2000).

In vitro estimation of accessible carotenes from cooked vegetables. In evaluating the bioavailability of provitamin A carotenoids in plant foods two important concepts involved are their bioaccessibility and absorption. Bioaccessibility of carotenoids from food sources may be affected by factors such as food matrix, dietary lipids, particle size of the food, protein and low bile secretion. In the case of green leafy vegetables, the leafy matrix seems to be an important factor that affects the bioaccessibility and consequently the bioavailability of carotenes (van het Hof *et al.*, 1998). In green leaves, carotene molecules are organized in pigment-protein complexes located in cell chloroplasts, which

have to be accessed to make the carotenes available. Cooking and reduction of particle size by grinding may reduce the matrix effects and have been reported to have the potential to increase the bioavailability of carotenoids (van het Hof *et al.*, 1998, Castenmiller *et al.*, 1999) possibly by disrupting and softening the plant cell walls and carotenoid protein complexes. However, complete disruption of the leaf matrix, for example by extensive cooking can also destroy carotenoids molecules (Rahman *et al.*, 19990).

In the present study there was a considerable range in percentage accessibility of β -carotene (8-29 %), from different leaves cooked without oil. This might be explained by different cell matrices of the vegetable varieties. Depending on vegetable source, cooking with sunflower oil or red palm oil increased the released amount of β -carotene by 3-20 times. It is well established that presence of dietary fat provides a hydrophobic domain within which carotenoids are solubilized and is known to stimulate bile flow, which is important for the formation of micelles from which carotenoids are absorbed into the mucosa (Parker, 1996; Furr and Clark, 1997). Enhanced bioaccessibility and absorption due to dietary fat has been shown in animal studies where consumption of cooked vegetables containing oil resulted in a significant increase in serum retinol concentrations (Jalal *et al.*, 1998; Takyi *et al.*, 1999; Huang *et al.*, 2000). The carotenes in red palm oil seemed to be highly available for absorption, as the leaves cooked with this oil had about twice as much in vitro accessible β -carotene as the ones cooked with sunflower oil. In the present study, depending on vegetable species, 39 to 94 % of the β -carotene content became available for absorption after cooking with oil.

Contribution of carotenes from vegetables to vitamin A requirement. There has been an extended discussion about the impact on vitamin A status with a diet consisting of dark-green leaves. De Pee *et al.* (1995) reported that the vitamin A status was not

improved when lactating women in Indonesia received stir-fried dark-green leafy vegetables as a daily supplement for 12 weeks. In contrast, increased serum retinol concentrations were found in three studies on children after consumption of green leafy vegetables (Jayarajan *et al.*, 1980; Takyi, 1999) or red sweetpotato (Jalal *et al.*, 1998) prepared with cooking oil.

The conventional conversion factor adopted by FAO/WHO (1988) for converting provitamin A carotenoids to retinol assumes that 1/3 of the total carotene content is absorbed into the mucosa and that 1/2 and 1/4 of absorbed β - and α - carotene are converted to retinol, respectively. In this study these conversion factors were used to estimate how much a portion of each vegetable relish might contribute to the recommended safe daily intake level of vitamin A, but instead of the absorption factor 1/3 the *in vitro* digestion data obtained in this study was used. The assumption made was that 100 % of the carotenes released after *in vitro* digestion is absorbed into the mucosa. The calculated amount of retinol was divided by the recommended safe daily intake level of vitamin A as adopted for planning purposes for individuals in developing countries, i.e. 550 μg RE (WHO, 1995). According to the results from present study, one portion (100 g) of green leaves cooked without oil may only constitute from 12 to 47 % of an individual's daily need of vitamin A, whereas green leaves cooked with either sunflower oil or red palm oil may provide enough daily retinol.

Conclusion

Sweetpotato leaves and cassava leaves like other dark green leafy vegetables have a potential of providing adequate vitamin A if prepared with oil. However, it is recommended that vegetables should be treated in a proper way to avoid loss of carotene content before and during cooking.

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Promoting indigenous wild edible fruits to complement roots and tuber crops in alleviating vitamin A deficiencies in Uganda

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Abstract. Micronutrients lack in most of the foods eaten by majority of Ugandans and consequently, micronutrient malnutrition is so high in Uganda. Due to low incomes, many people cannot afford to buy exotic sources of these nutrients. Local sources of nutrients should be sought, as a food-based approach to complement supplementation and fortification efforts that currently leave a lot of ‘hard to reach people’ not served. Indigenous fruits could be such nutrient sources. Unfortunately the nutrient content for most of them is not known. Chemical analyses were carried out on *Physalis minima* and *Carissa edulis* fruits and indicated that they are rich sources of micronutrients especially minerals. These indigenous fruits compared well with the exotic ones (mangoes, paw paws and *Physalis peruviana*) in nutrient content.

Introduction

Like many developing countries, Uganda has nutritional problems. The food on which the majority of Ugandans feed lacks essential nutrients. Consequently, many people especially children, suffer from malnutrition. Uganda, ranks 30th among countries with the highest under- five year’s child mortality rates in the world (UNICEF, 1998). According to UDHS (2000/01), 28% of children in Uganda below 5 years of age suffer from vitamin A deficiency (VAD), 64% suffer from iron deficiency anaemia (IDA) and 60% suffer from

various iodine deficiency disorders (IDD). Over 50 percent (52%) of women of reproductive age suffer from vitamin A deficiency and 30% from iron deficiency anaemia. Reddish, yellow and orange fruits provide carotene and many contain folic acid, calcium, iron, vitamin C and anthocyanins (FAO, 1988). Fortunately, Uganda is endowed with many varieties of such indigenous food plants (WWF, 1993) that have an outstanding potential to alleviate nutritional deficiencies among vulnerable groups. Unfortunately, utilisation of indigenous food plants has steadily declined mainly due to lack of knowledge on their nutrient value resulting from limited research done (Kiremire *et al.*, 2002). These fruits are further threatened by population pressure in the country and man’s activities like clearance of forested areas to set up farmlands. A large proportion of Ugandans cannot afford to produce or buy exotic fruits due to input costs and price implications respectively. This could partly be responsible for the observed high malnutrition especially in micronutrients. Apart from providing nutrition to the diverse bird community, these indigenous nutritious fruits have not yet been given serious attention in Uganda. This paper presents the nutrient content of two wild edible fruits wild plums (*Carissa edulis*) and goose berries (*Physalis minima*) as a deliberate effort to promote consumption of locally available and easily accessible indigenous fruits in alleviating vitamin A deficiencies. The dietary

diversity that will be created could go along way in alleviating the nutritional problems that are facing Uganda and Africa in general. Comparison of nutrient content of these wild fruits with the cherished exotic ones like mangoes and paw paws revealed a fair comparison.

The aim of this study was to highlight the potential of fighting malnutrition in Africa using the locally available and easily accessible food plants by determining the nutrient content and promoting utilisation of indigenous fruits.

Materials and methods

The fruits that were studied were got from the wild in Rukungiri District, South Western Uganda.

Nutrient content analyses. Proximate analyses on crude protein, crude fat, dietary fibre and micro nutrient determination of β -carotene, vitamin C and minerals (calcium, iron phosphorus, magnesium and potassium) were carried out.

Moisture content. Moisture content (MC) determination of the samples was carried out following procedures in Kirk and Sawyer (1973). Aluminium dishes were washed, dried in the oven, removed and allowed to cool in a desiccator. The dishes were weighed empty (A) and after adding the samples (B). The sample-containing dishes were placed in the oven and the oven temperature adjusted to 65°C and left overnight. The samples were then removed, placed in a desiccator to cool and weighed again (C) and the MC of the sample was calculated.

Crude protein determination: The Kjeldahl method that is outlined in Pearson's laboratory techniques (1973) and AOAC (1990) was followed. Samples were macerated in a blender and about 1g of each sample weighed in previously washed and dried Kjeldahl flask. One tablet of Kjeldahl catalyst was added to the flask. 10mls of 98% H_2SO_4

were added to Kjeldahl flask and the flask was heated starting lightly (350°C) and finally heating strongly (500°C). Heating was continued until the sample in the flask turned colourless. Distillation was carried out using a semi auto Kjeldahl machine (2200 Kjeltec auto distillation). The sample was quantitatively transferred to the distillation tube. Kjeldahl flasks were washed twice with 25ml portions of distilled water adding the washings to the distillation flask. 30mls of 2% boric acid were measured into a 500ml conical flask and the conical flask was placed in position to collect the distillate making sure that the air condenser was immersed in boric acid. The distillation was continued until the colour of boric acid changed from purple to green. The distillate was titrated against standard hydrochloric acid solution (0.05N) and results were computed based on titres.

Crude fat determination. The Soxhlet method (AOAC 1990) was followed using Soxtec equipment for determination of fat content. The sample was weighed in a dry thimble (Swt), a pad of cotton wool was inserted into the thimble to prevent the sample from overflowing through frothing. A 200ml beaker was weighed (W_1) and 30mls of petroleum spirit (boiling point 40-60) were added. The sample-containing thimble and the beaker were placed on the soxtec machine (Soxtec system HT). Boiling was started with the thimble immersed in solvent for 15 minutes. The thimble was raised and extraction carried out for 45 minutes. Stop corks of the machine were closed and solvent distilled off the extracted oil in the beaker. The beaker was removed, put in the oven at 100°C for 30 minutes to drive off any water. The beaker was put in a dessicator and allowed to cool before weighing it (W_2) and the percentage fat content was calculated.

Dietary fibre determination. The dietary fibre was determined using Acid Detergent Fibre (ADF) solution following procedures outlined by Kirk and Sawyer (1973). The solution was prepared as follows: 28mls of 98% H_2SO_4 were

carefully added to and mixed with 600 ml of distilled water. 20g of Cetyl trimethyl ammonium bromide (CTAB) were added and stirred until it dissolved. The acid detergent was made up to 1 litre with distilled water mixed thoroughly. The sample was macerated and 1.0g of the sample were weighed in an 1 litre beaker. 100mls of the acid detergent solution were added to the beaker followed by 2.0ml of dekalin. The mixture was heated to boiling under reflux for 1 hour. Heating was controlled to minimise foaming by adjusting the control knob. The sample digest was filtered with a crucible previously dried in the oven at 100°C. The beaker was washed with boiling distilled water filtering the content through the same crucible 3 times. The final washing was done with acetone and the residue was collected into a clean crucible dried at 100°C for 8 hours in the oven. Dietary fibre of the sample was calculated. 2.1.5 Vitamin C determination: Vitamin C was determined following procedures in Kirk and Sawyer (1973). 5g of sample were weighed into a clean mortar. The sample was macerated in a mortar using a pestle with 5ml portions of 5% trichloro acetic acid (TCA) being added at a time. The extracts were quantitatively transferred into a clean 50ml volumetric flask and made up to volume with TCA. The flask was stoppered, shaken to ensure thorough mixing and the mixture was filtered using a filter paper (Watman no.1). 2,6-DCPIP Solution was standardised using ascorbic acid standard solution of concentration 1.08 mg/ml. 2mls of standard ascorbic acid were titrated with DCPIP until a pink colour that persisted for 3-5 seconds was seen. 5mls of extract were pipetted into a clean conical flask and carefully titrated against the standard DCPIP solution until a pink colour that persisted for 3-5 seconds was observed. The volume of DCPIP solution used was read from the burette and used to calculate the vitamin C content of the sample.

β-carotene determination. β-carotene was determined following procedures outlined by Ritter and Purcell (1981).

Extraction of β-carotene. Samples were separately weighed out and placed in a mortar; 5-7mls of hexane-acetone mixture in a ratio of 1:1 were added. A pestle was used to stir the sample-solvent mixture to facilitate extraction. The extract was transferred to a 50ml volumetric flask and extraction was repeated 5 times with 5-7ml portions of solvent mixture adding the extract of volumetric flask each time to the flask contents. When the sample was free of beta-carotene, the volume of the extract was made up to 50mls with the solvent mixture. The volumetric flask was kept away from light by wrapping it with aluminium foil to prevent photo degradation of beta-carotene.

Concentration of beta-carotene. The extract was placed in a clean, dry 100ml beaker and the beaker was heated gently on a hot plate in the fume cupboard with the fan on until all the solvent evaporated. The beaker was then removed and allowed to cool after which 2.0mls of pure solvent mixture were added to dissolve the residue; 1.0ml of the dissolved extract was pipetted and transferred to a packed column of magnesium oxide. A fresh solvent mixture was used to elute the extract from the column. The deep coloured band of beta-carotene was collected in a 50ml volumetric flask until the eluate was colourless, the extract was made up to volume, with the extracting mixture, shaken to dissolve and put in the dark ready for absorbance reading. 15mg capsules of beta-carotene were dissolved in 100mls of hexane to make stock solutions. Using a spectrophotometer (SP 20), the absorbencies of the stock solutions were read at 450nm. A standard curve of absorbance Vs concentration (microgram/ml) was plotted. Using a spectrophotometer (SP 20), absorbencies of the samples were read. By using their absorbencies, the beta-carotene concentrations of the samples were read off the previously prepared standard curve.

Mineral content determination. The mineral content of the samples was determined

following procedures by Kirk and Sawyer (1973) and AOAC (1990). Samples were digested with the digestion mixture prepared as outlined: 0.42g of selenium powder were weighed into a beaker. 14g of lithium sulphate were added followed by 350ml 30% hydrogen peroxide and mixed well. 420ml of conc. H_2SO_4 were added slowly and carefully while cooling in an ice bath. 0.2g of ground sample was added into a dry clean digestion tube and 5mls of digestion mixture were added to the tube. The mixture was digested at 360°C for 2 hours until the solution turned colourless. The contents were allowed to cool and 25mls of distilled water were added and shaken until no more sediment dissolved. The volume was made up to 50ml with water and shaken. They were allowed to settle and the clear solution was decanted off for phosphorus, calcium, sodium, Iron, magnesium and potassium analyses.

Phosphorus determination. 12g of ammonium molybdate were dissolved in 100mls of warm distilled water and then cooled. 0.291g of antimony potassium tartrate were separately dissolved in 100mls of distilled water. Both solutions were made to 2l with distilled water. The mixture was shaken thoroughly to ensure proper mixing. Ascorbic acid reducing reagent was prepared by dissolving 2.108g of ascorbic acid into 400mls of ammonium molybdate/antimony potassium tartrate. Working standard solutions of 0.1, 0.2, 0.4, 0.6 and 0.8-ppm concentration were prepared. 0.5 ml aliquots of the working standard solutions were transferred to a 25ml volumetric flask and diluted with distilled water followed by 5mls of the ascorbic acid reducing reagent. The mixture was made to the mark with distilled water and mixed thoroughly. The mixture was left to stand for 40 minutes prior to absorbance reading on a spectrophotometer (SP20). Similar procedures were followed to take absorbance reading of the samples. A calibration curve of absorbance against concentration was plotted using the working standard solutions. Phosphorus concentrations (ppm) in the samples were read from the calibration curve

using the previously obtained sample absorbencies. The phosphorus concentrations in the samples were then computed to mg / 100g of the edible plant portion. In the analysis of magnesium, sodium, calcium, potassium and iron, working standard solutions were prepared for each element from the stock solutions. Standard solutions and samples were prepared in a solution containing lanthanum chloride to overcome the problem of chemical and ionisation interferences. Working standards were then aspirated on the Atomic Absorption Spectrophotometer (Pearkin-Elmer 2380) so as to calibrate the machine to give its readings in milligrams per litre. Samples were aspirated on the calibrated Atomic Absorption Spectrophotometer and the concentration of each element in the sample solutions was read directly from the machine in milligrams per litre. The phosphorus concentrations in the samples were then computed to read in mg/ 100g of edible plant portion.

Statistical data analysis. Data were analysed using a one way Analysis of variance (ANOVA) using Genstat Version 5, Release 3.2 (Lawes Agricultural Trust Roth amsted experimental Station, USA).

Results and Discussion

Nutrient content of *Carissa edulis* and *Physalis minima*. Results of chemical analyses done on gooseberries (*Physalis minima*) and wild plums (*Carissa edulis*) indicate that they compare well with mangoes and paw-paws (Table 1, Figure 2). *Physalis minima* compares very well with its exotic counterpart, *Physalis peruviana*, in sodium, iron, phosphorus, calcium, beta-carotene, phosphorus and dietary fibre content. *Physalis minima* is however higher in protein content than *Physalis peruviana* and lower in potassium content (Figure 1). No significant difference in minerals like calcium, sodium, potassium, phosphorus, iron and other nutrients like dietary fibre and beta-carotene were observed between these two

fruits. *Carissa edulis* was equally high in minerals. People fear to get embarrassed by harvesting and consuming wild fruits. Malnutrition has taken advantage of this and left many of them either severely or chronically malnourished. Malnutrition leads to an unproductive population that cannot ensure its food security and this exacerbates poverty. Tackling malnutrition on the African continent

will go a long way in ensuring food security and improving the economic well being of the Africans. Domestication and conservation of the currently wild, nutritionally sound, environmentally adapted and locally available fruits along with the exotic ones will go along way in alleviating malnutrition and will ensure dietary diversity that is a close correlate to household food security.

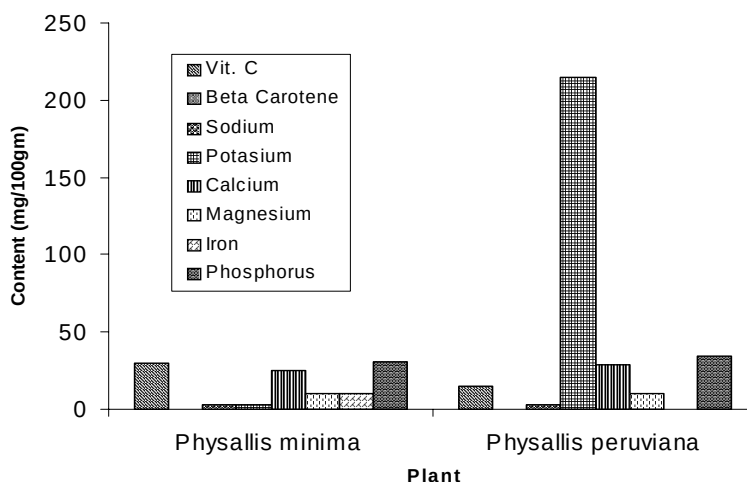


Figure 1: Nutrient content in *Physalis minima* and *Physalis peruviana*.

Table 1: Nutrient contents of *Physalis minima*, *Carissa edulis*, *Physalis peruviana*, mango and paw paw fruits (ripe and fresh) compared.

Nutrient	Content per 100g				
	Mango	<i>Physalis peruviana</i>	Paw paw	<i>Physalis minima</i>	<i>Carissa edulis</i>
Moisture content (%)	84.6	90.1	88.5	89.9	84.6
Crude protein (g)	0.5	1.1	0.5	2.04	0.3
Fat (g)	0.2	14	0.1	0.056	Trace
Vitamin C (mg)	37	114	60	29	3.24
Retinol equivalent (ig)	300-3000	18.3	810	28.9	256
Sodium (mg)	2	2	5	1.8	1.79
Potassium (mg)	180	210	200	2.43	198
Calcium (mg)	12	28	23	25	10
Magnesium (mg)	13	7	11	7.8	4
Iron (mg)	0.7	0.3	0.5	0.28	0.56
Phosphorus (mg)	16	34	13	30	24
Dietary fibre (g)	2.6	2.4-2.9	2.2	2.7	2.65

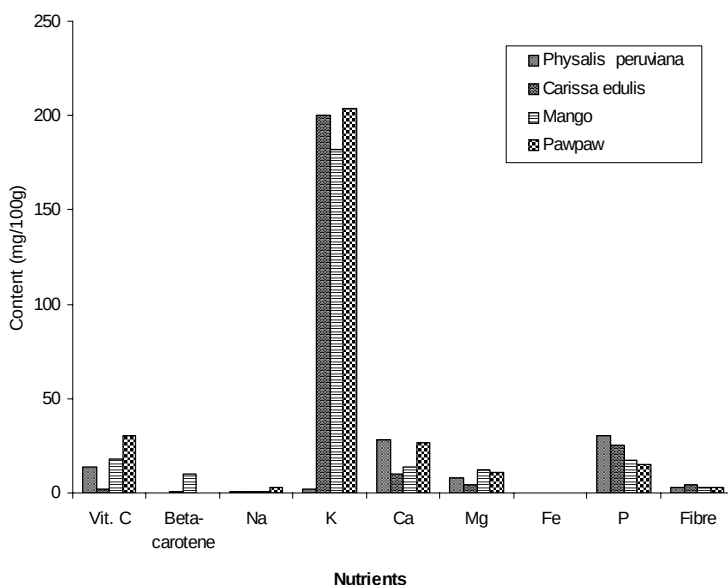


Figure 2: Nutrient content of *Carissa edulis*, *Physalis minima*, mango and pawpaw.

Conclusion and Recommendations

Carissa edulis and *Physalis minima* are as nutritionally important as the exotic fruits. There is too much stigmatization on indigenous fruits due to the notion that they are nutritionally inferior and are a poor man's food. Such stigmatization can be broken down with proper sensitization of the public. Research therefore should be done on more indigenous fruits and results of such studies be disseminated to the public. This will ensure dietary diversity and food security of marginalized and poor communities that make up the majority of the developing world.

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Partnership: An approach to promote orange-fleshed sweetpotato, experiences from Uganda

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Abstract. Micronutrient malnutrition, is widespread in Uganda. In late 2000 a partnership using a multisectoral approach was initiated to address vitamin A deficiency (VAD) using orange-fleshed sweetpotato (OFSP) in a community in five zones of Luwero district in Central Uganda. The partners from different organizations and sectors field-tested OFSP in the district, created awareness of the potential value of OFSP in combating VAD, improving food security and household income. The initial partners were the National Agricultural Research Organization (NARO), the International Potato Centre (CIP), Child Healthy and Development Centre of Makerere University Medical School, Luwero District Agricultural Extension (LDAE), and the non-government Organization, Volunteer Efforts for Development Concerns (VEDCO). To accelerate promotion and dissemination of OFSP the partnership at different times included different players from the different sectors. To date more than 30 districts in the country have received planting material to initiate multiplication and dissemination of OFSP. Promotion of OFSP is increasingly attracting the private sector leading to new sweetpotato products, increased sale of OFSP vines and storage roots by farmers. The multisectoral approach involving different partners has had a positive impact as reflected in the increased demand for OFSP planting

material from research institutes and agricultural development research centers, individual farmers and farmer groups.

Introduction

Micronutrient malnutrition, primarily due to diets poor in bioavailable vitamins and minerals is widespread in Uganda, and in developing countries. Iron, vitamin A and zinc deficiencies are the most widespread nutrition deficiencies in the world today, affecting over 3.5 billion people globally (Ruel, 2001). The root cause of micronutrient malnutrition is poor quality diets, characterized by high intake of food staples, but low consumption of animal and fish products, fruits, lentils, and vegetables, which are rich sources of bioavailable minerals and vitamins. Consequently, most of the malnourished are those who cannot afford to buy high-quality, micronutrient-rich foods or who cannot produce and consume these foods.

More than 90 countries are categorized by the World Health Organization (WHO) as having a public health problem as a result of clinical (very severe) and/or sub-clinical (severe) vitamin A deficiency (WHO, 1995). Uganda is included in the clinical vitamin A deficiency category (WHO, 1995) due to approximately one third (28%) of Ugandan children, and 60% of women being vitamin A

deficient (UDH, 2001). Globally, an estimated 3-million preschool-age children have visible eye damage due to vitamin A deficiency (VAD). Annually, an estimated 250,000 to 500,000 preschool children go blind from this deficiency, and about two-thirds of these children die within a few months after going blind. VAD increases children's risk of common illnesses such as respiratory and diarrheal diseases, measles, and malaria, impairs growth, development, vision, and immune systems, and in severe cases results in blindness and death (Ruel, 2001). In women Vitamin A deficiency increases the risk of dying during pregnancy, as well as giving birth to low weight children and may increase the spread of HIV infection leading to AIDS. There are several approaches that are effective in combating vitamin A deficiency. These include, capsule supplementation, food fortification, diet diversification and public health measures. The rural and urban poor cannot afford expensive vitamin A-rich foods, such as fish oils, liver, milk, eggs and butter, which contain vitamin A in its true form (retinol), which can be used directly by the body. Plant foods and vegetables contain precursors, or pro-vitamin A (beta-carotene) and other carotenoids that the human body can convert to vitamin A.

Food-based strategies to combat vitamin A deficiency may involve modifying people's diets, by providing plants with large amounts of b-carotene or by breeding new varieties of plants with larger amounts and more bioavailable b-carotene. As a long term goal to combat VAD, consumption of a variety of local foods rich in vitamin A will provide adequate vitamin A. Consumption of these foods requires purchasing them or producing and consuming them on small holder farms of low income families. OFSP have potential to provide adequate vitamin A intake to the resource-poor, especially children. Prior studies have shown that OFSP are among the most promising plant sources of β -carotene (Low *et al.*, 1979; 2001; Hagenimana *et al.*, 1999; Mukherjee and Ilangantileke, 2002). This paper highlights the important role

partners have played in dissemination of OFSP in Uganda.

Early Attempts to introduce OFSP in the farming systems of Uganda. There were attempts to introduce OFSP in the farming systems of Uganda in the early 1980s but failed. Farmers and consumers rejected OFSP clones introduced from Taiwan, Mainland China, and the International Institute of Agriculture (IITA) because of low dry matter content (<30%) and squash-like flavor of clones (Mwanga *et al.*, 1991). In 1999 the National Agricultural Research Organization (NARO) officially released the "NASPOT 5", the first OFSP cultivar to be released by the national sweetpotato program (Mwanga *et al.*, 2003). However, dissemination of "NASPOT 5" was very slow. In an independent project, attempts by Child Healthy and Development Centre (CHDC) of Makerere University to improve child growth through improved quality of diet by promotion of rabbit rearing in Luwero District in mid 1990s failed. These plus perhaps other examples of previous undocumented interventions of supplementation, agricultural interventions, and education to improve dietary quality were all necessary but insufficient approaches. Coordination between sectors was missing. Multidisciplinary teams had to work together as partners to design and implement strategies to tackle the problem in a sustainable way.

Food-based approaches focus on increasing the amount of micronutrients consumed in the diet and on making a larger share of these nutrients bioavailable (readily absorbed by the human body). Food-based approaches are complex and require collaboration or partnership between a variety of sectors such as agriculture, nutrition, education, and economics. The realization of the need for a partnership and sector approach led to initiation of the Luwero Child Nutrition Project and eventually to the promotion of beta carotene-rich OFSP.

Background to the Luwero Child Nutrition Project. In 1997 The Child Health and

Development Centre (CHDC) of Makerere University (MU) together with Volunteer Efforts for Development Concerns (VEDCO), implemented a child nutrition project in 5 zones in Luwero District. The major objective of the project was to promote child growth through improved quality of diet. The activities included promotion of rabbit rearing for household diet, especially for children, monthly weighing of children, nutrition education, individual counseling and referral of mothers with malnourished and sick children, periodic distribution of vitamin A capsules and deworming medication. Rabbits had already been introduced to Luwero by VEDCO as an economic initiative. CHDC therefore came in to add value to the rabbits by promoting them for household consumption, for the benefit of children and to address micronutrient malnutrition. VEDCO and Luwero District Agricultural Extension (LDAE) provided extension services in rabbit management and rearing, and other agricultural related services. The Thrasher Foundation, a US based research initiative, funded the project during 1998 to 2000.

The Orange Fleshed Sweetpotato Project in Luwero District. In late 2000, the International Potato Centre (CIP) approached Micronutrient Operational Strategies and Technology (MOST) through the CHDC, to identify a community where the 'orange-fleshed sweetpotato project' could field-test OFSP to address vitamin A deficiency. The opportunity was seized by CHDC to continue providing services for nutrition improvement services already implemented in Luwero District. The National Agricultural Research Organization (NARO) through Namulonge Agricultural and Animal Production Research Institute (NAARI) and Kawanda Agricultural Research Institute (KARI) were included to plan for field-testing of sweetpotato in the existing project areas. Sweetpotato was considered a viable product for the project since 80% of Luwero households depend on sweetpotato as a staple food.

Implemented Project Activities

The partners (shown in parentheses below) implemented different components of the project in five zones of Luwero District.

Growth promotion (CHDC/MU, Healthy Department Luwero District, VEDCO). The partners executed monthly weighing of children, nutrition education and counseling, periodic deworming, and vitamin A capsule supplementation.

Crop and Field Management (NARO/NAARI, CHDC, CIP, VEDCO). The partners conducted demonstrations on garden-preparation, planting technology and crop management, and on-farm field-testing of OFSP clones. Rapid multiplication of planting materials was carried out to ensure availability of vines to farmers in each zone.

Post-harvest Technology (NARO/KARI, NAARI, CIP, CHDC, VEDCO, Luwero District Agricultural Extension (LDAE)). The partners: (1) carried out demonstrations on processing of sweetpotato into various products suitable for young children's meals. (2) Provided hands-on experience in preparation of children's meals. (3) Demonstrated technology for preservation and storage of sweetpotato for long time use. (4) Conducted palatability tests to measure acceptability of sweetpotato varieties and products.

Monitoring and evaluation (NAARI, CIP, CHDC, VEDCO, LDAE, farmers). NARO together with farmers specifically monitored crop management and emerging field problems. NARO also compiled data to assess yield performance, disease, pest resistance, and palatability of the different sweetpotato varieties. Other aspects of the project such as responses of the communities to project benefits were jointly monitored by all the partners.

Project Achievements

The following were the major achievements of the Luwero OFSP project accomplished through a strong partnership of various collaborators, including the community.

- Demand for nutrition and agricultural services were enhanced greatly.
- The project strengthened leadership of existing community groups to address not only economic empowerment, but also health and nutritional status of vulnerable groups like children
- Nutrition improvement for children was put on the communities' priority agenda. Communities demonstrated this through the implementation of community-initiated children's days to promote what they had benefited from the project.
- The OFSP project was appreciated as a means of improving household food security because the OFSP was high yielding and grew faster. It was nutritious and was liked by children. It is also a viable income-generating product of the project.

The Luwero Community. The community was led and organized by five leaders from each project zone. The leaders were responsible for mobilization, and training of community members. They were also responsible for monitoring progress of implemented activities.

Volunteer Efforts for Development Concerns (VEDCO). VEDCO is a community-based organization whose mission is to ensure sustainable economic empowerment of smallholder farmers and micro-entrepreneurs, organized in self-help groups. The organization acted as an entry point to the target communities, for implementation of nutrition-related activities.

Child Health and Development Centre (CHDC), Makerere University: provided the technical input on nutrition and health for growth promotion.

National Agricultural Research Organization, (NARO). Two research institutions, NAARI, and KARI together with CIP, conducted extensive collaborative research on the OFSP, internationally and in Uganda. NARO was responsible for introducing, breeding and field-testing of the sweetpotato cultivars. KARI coordinated post-harvest technology.

MOST, a USAID Micronutrient Program was responsible for co-ordinating and providing logistical support to the project through the CHDC, Makerere. The MOST strategy aims at reducing micronutrient deficiencies related to Vitamin A, anaemia and iodine deficiency through an appropriate mix of interventions constituting a complex, yet affordable program.

Emerging Challenges

The following were the major challenges that emerged during the project:

- To create awareness and continue to emphasize to parents that children are special and require special care to keep them healthy and well
- Have the OFSP widely available on the open markets and in all households
- Need to encourage more caregivers to attend monthly growth promotion sessions for nutrition
- Conduct research on the OFSP retention of vitamin A through the different processing methods
- Inadequate supply of OFSP planting materials
- Expansion of project to cover the whole of Uganda

Expansion of Partnership. Funding of the OFSP by USAID in Luwero District was short, 2001 to 2002 due to the AlKeida bombing of the twin tower in New York on September 11, 2001 that led to sudden budget cuts which affected numerous US funded projects. Although USAID funding of the OFSP project stopped in 2002, partnership activities

continued with partners funding different components from different funding sources. The following activities or events led to expansion of the activities to other districts and increased the number of partners. The expansion of the partnership and activities led to rapid dissemination of planting material of OFSP in Uganda.

The orange-fleshed sweetpotato promotion initiative. Promoting the OFSP is one of the ways of focusing on available Ugandan foods with added value. The OFSP promotion effort was started in the pilot District in Luwero in 1999 as a joint multi-sectoral effort involving NARO, CIP, VEDCO, Makerere University Medical School, Ministry of Health, Local Government and farmer groups, to introduce OFSP in the farming and food systems of Uganda.

To date the promotional effort has widened and includes many partners whose roles vary. The key ones are:

- 1) the National Agricultural Research Organization (NARO)
- 2) the International Potato Centre (CIP)
- 3) the Potato and Sweetpotato Network (PRAPACE)
- 4) Child Healthy and Development Centre (CHDC), Makerere University
- 5) Non-Government Organizations
VEDCO (Volunteer Efforts for Development Concerns), BUCADEF (Buganda Cultural Development Fund) JAF (James Arwata Foundation), SOCADIDO (Soroti Catholic Diocese Development Organisation), AFRI-CARE and World Vision
- 6) Senior Family Charity Foundation in the USA
- 7) Farmer groups,
- 8) CBOs (Community based organizations)
- 9) REFSO (Rural Energy Food security organisation)

Most of the sweetpotato breeding work to produce new OFSP cultivars and a large proportion of on-farm testing and technology

transfer is supported by the McKnight Foundation.

Role of local government and political leaders.

The role of local government and political leaders has had a significant effect in mobilizing and sensitizing communities to the problems of vitamin A deficiency and the great need to plant and consume OFSP to combat the deficiency. Below are examples where political leaders have been actively involved in sensitizing communities and/or dissemination of OFSP.

The Minister for Agriculture officiated opening of vitamin A for Africa (VITAA)-Uganda Workshop at NAARI (4-6 February 2002). The inauguration was televised and covered in local newspapers and radio. He urged all concerned to encourage every homestead to grow OFSP to combat Vitamin A deficiency. The Honorable Minister For Agriculture does not only promote use of OFSP to combat Vitamin A deficiency but he also grows it on his farm at Kikonde, Bamunanika in Luwero. He is practical. Representatives from the districts of Gulu, Lira, Kabale, Kisoro, Masindi, Kamuli, Soroti, Kumi, Busia and Pallisa who attended the workshop followed the example of the minister; they took OFSP vine cuttings to their districts to start sensitizing the local communities.

Queen of Buganda Launch of OFSP. Her Royal Highness, the Queen of Buganda, known locally as the *Nabagereka* launched a campaign at Nyimbwa Sub-county Headquarters near Bombo in Luwero District on May 15, 2002 to promote OFSP in the nine districts of Buganda in Central Uganda to combat vitamin A deficiency. The launch built upon two years of research by child health experts at Makerere University, NARO, and CIP. The Queen appealed to all Ugandans to grow and feed OFSP to fight malnutrition and poverty. Local officials named one of the new varieties *Nabagereka* to motivate Ugandan mothers to grow orange-fleshed plant types.

The *Nabagereka*, the official wife of the Kabaka or King of Buganda, is held in high esteem by her subjects and plays a pivotal role in mobilizing development efforts in the Buganda Kingdom which covers 10 districts in Central Uganda: Kiboga, Masaka, Wakiso, Mpigi, Mukono, Mubende, Kayunga, Luwero, Rakai, and Kalangala. During the launch, there were exhibits by farmers, research institutes and NGOs. Different cultivars of OFSP (Ejumula, SPK004, NASPOT 5, Sowola-6, Sudan, and Kala) and sweetpotato products such as chapatti, doughnuts, cakes, crackers, pancakes, porridge and bread were sold. The Luwero farmers sold OFSP vine cuttings at 10,000/= Uganda shillings (USD 5.00) a bundle of 600 vine cuttings of 30 cm length each. They also displayed and sold vines and products of the OFSP. The event was widely publicized on radio, television and newspapers. The Queen's launch of OFSP subsequently led to increased acceptance and high demand for OFSP.

The Uganda Parliamentarians' Forum on Food Security, Population and Development (UPFFPD). Involvement of the UPFFPD started during a meeting when all the Future Harvest centers based in Uganda were invited by the UPFFPD to address matters related to food security and income generation in Uganda. The parliamentarians had special

sessions (4/3/2003, 4/4/2003, May 2003) with NARO, CIP and NARO staff. The forum is an interest group of 60 members of parliament formed to advocate for and where possible implement and promote programs to improve food security and general livelihoods in the country.

CIP and PRAPACE used this opportunity to brief the forum on its research and development activities on potato and sweetpotato in Uganda and in other countries. It is this briefing that generated interest among the executive committee of the forum and requested for a follow up discussion on possible collaborative plans. Thereafter, NARO, CIP-VITAA and PRAPACE agreed to initiate follow up activities ranging from dissemination of planting materials of improved varieties of OFSP in pilot constituents to big proposal development to cover more than 20 districts in Uganda. It was at this point that CIP-VITAA together with PRAPACE provided support to the forum by providing starter-planting material of the popular varieties for a few pilot constituencies as indicated in the Table 1. It is also important to note that some parliamentarians ordered and got more planting material for their areas.

Five pilot constituencies were targeted by the forum to benefit from the planting material. These included mainly the cattle corridor in Katakwi and Kotido, which experience severe

Table 1: Distribution of OFSP planting material in pilot constituencies of Uganda through the Parliamentarians Forum on Food Security and Population Development, May, 2003.

Constituency	Number of bundles distributed*	Estimated number of cuttings	Estimated area harvested (ha)	Estimated of Households benefited**
Kotido	200	600000	20	6000
Katakwi	246	590400	19.7	5904
Jinja	110	264	8.8	2640
Rakai	80	168	5.6	1680
Kalangala	80	168	5.6	1680
Totals	636	1.430.400	59.7	17904

* A bundle has 800 vines each capable of giving 3 vine cuttings.

** Major assumption: Each targeted household receives at least 100 vine cuttings.

famine after prolonged drought and were largely supplied with orange-fleshed varieties SPK 004 (Kakamega) and Ejumula. Jinja district in the East was also targeted and received orange varieties. Rakai and Kalangala districts in the Central which experience frequent food insecurity yet grow and consume a lot of sweetpotato, were given the high yielding but yellow varieties, Tanzania and Naspot 1.

Source of OFSP and varieties supplied. All the vines were obtained from progressive farmers from Luwero and Mpigi districts who have concentrated in the multiplication of clean healthy planting materials of popular varieties as an income generating activity. The consignment supplied consisted of OFSP (81%) and others (19%). A bag consisting of 2400 vine cuttings is sold at Ugshs. 6000 = US \$ 3. These farmers originally participated in the first pilot NARO/ CHDC/ VITAA – USAID MOST project on the promotion of OFSP for the increased intake of Vitamin A in resource poor households of Luwero district. Although the project was concluded in May 2002, farmers have continued with the scaling-up of activities mainly multiplication and dissemination of clean healthy planting materials, development of OFSP based processed products, and storage root production targeting the markets. Interview reports, their experiences, farmers' experiences, and OFFSP success stories, and lessons learnt frequently appear on the VITAA web site.

Handing over ceremony

An official hand over ceremony was held on 15th May, 2003 at the premises of Uganda Parliamentary Chambers during which Dr. Fina Opiyo, the VITAA co-ordinator and Director of Namulonge Agricultural and Animal research Institute of NARO handed over two lorries full of sweetpotato vines to the Hon. Grace Akello the Chairperson of the Forum executive committee and by then was one of the state Minister for Ministry of Gender,

Labour and Social Development. About thirty parliamentarians from the forum witnessed this event. Also in attendance were partners from BUCADEF, CIP- Nairobi, PRAPACE, NARO and individual farmers from Central Uganda. The journalists from both the print and electronic media covered the function. It formed an item on the evening news broadcasted by the Uganda Television covering the all country and the Central Broadcasting Station (CBS), a private local radio station covering almost eighteen districts of Central Uganda.

The forum members exhibited a lot of enthusiasm and are still keen to promote the activities food security in their constituencies. Sweetpotato provides a great potential for the purpose due to its wide adaptability and acceptability to all Ugandan communities. However the forum is constrained by limited financial resources that are much needed to undertake the activities. CIP-VITAA, PRAPACE, and NARO remain committed to work with the forum to mobilize resources to cover larger areas in Uganda, particularly with orange-fleshed types. Technology transfer through this channel could have much impact at household level since they reach the grassroots. They can also link up quickly with the active community based set ups and the local governments in their constituencies to reach more people. High interest by the MPs has demonstrated the importance attached to food security crops such as sweetpotato to address food shortages in their areas.

Dissemination and commercialization of orange-fleshed sweetpotato through Farmer Field Schools and VITAA partnerships in Eastern Uganda. Farmer field schools (FFS) integrated crop management of sweetpotato started in August 2001 and the orange-fleshed varieties were introduced during launching of OFSP to combat VAD on September 27, 2002 in Gweri sub-county, Soroti district. All the vines were sourced from Luwero district, Nyimbwa sub-county. Since the launching 872 bundles of 600 vines each worth Ug.Sh. 5,232,000 have been bought from original

farmers where CHDC worked in partnership with CIP, NARO, VEDCO, and PRAPACE. Farmers from Luwero went to Soroti and trained their fellow farmers in agronomic practices, product development, and rural income generation through the sale of OFSP (Table 2). In 2002 two FFS (Apa Amora and Okunguro) in Kyere, Soroti District sold about 700 kg of dry chips to Maganjo factory in Kampala for further processing into nutri-porridge flour.

Projections. Slicing and immediate sale of dry chips of OFSP stimulated interest by individuals and other groups in Soroti District for further production of orange-fleshed varieties, and by 2003, nine farmer field groups, 20 SOCADIDO community-based groups in Kumi and Soroti districts, several individual spill over within and beyond the project areas such as Bugondo had grown the orange fleshed varieties namely Ejumula and Kakamega (SPK004). A conservative figure of above 70 acres was grown in the second season of 2003 alone and was estimated to produce not less than 700 tons of fresh roots.

Sustainability. Soroti local government and National Agricultural Advisory Services (NAADS) program have internalized the orange-fleshed varieties as a commercial crop in selected sub-counties. The district leadership and CIP is spearheading the search for and linkage to alternative markets such as

encouraging consumption of orange-fleshed in boarding schools and other factories including those processing animal feeds. Key district leaders urged their people to grow more orange-fleshed varieties for domestic and outside district market, and encouraged the producers to include OFSP on their daily menu to alleviate the nutritional deficiency of Vitamin A.

Lessons learnt from the fields.

Commercialization through processing seemed not profitable meanwhile the use of feeding to boarding schools was more promising. Awareness of the crop about its nutritional and marketability benefits promotes popularity. Through FFS an inferior crop can be easily be popularized. Farmers can accept to pay for the cost of inputs where they expect tangible returns. Farmers have a potential to supply quality-planting material after internalizing the concepts and practices learnt through self-learning approach. Farmers' collective participation is a tool of capital mobilization and a driving ingredient for self- accountability as skillful performance and financial improvement by the group member(s) portrays community excellence. Farmers are thirsty for a positive change in production and income. Evidence of economic success through changed technological approaches to production by farmer field graduates is not only exemplary but also creates anxiety of others to explore similar

Table 2: Distribution of orange-fleshed sweetpotato planting material in Soroti District, Uganda.

Season	Beneficiary	Source	Bags	Cost/bag	Total cost Ug. Shillings	Paid by
2002	SOCADIDO	JAF	256	6000	1,536,000	SOCADIDO
	NAADS	JAF	600	5,000	3,000,000	NAADS
	Launching	CIP	27	8,000	216,000	CIP
	FFS groups	CIP	20	6,000	120,000	CIP
	FFS groups	Gweri	16	5,000	80,000	FFS
2003	FFS groups	CIP	196	5,000	980,000	CIP
	FFS groups	Gweri	45	5,000	225,000	FFS
Total			1160		6,157,000	

avenues to improve farming techniques and enhance adoption as an avenue of improving on food security and household incomes. Researchers, NGOs, policy makers and farmers must collaborate in developing, designing and implementing strategies for transforming agricultural production and augmenting successful attainment. Experience sharing and availing opportunity to FFS member(s) to become technical instructor(s) (facilitators) of otherS promotes ambition, encourages active participation, enhance self-confidence and leadership building. Farmers are willing to drop a crop variety for a more promising one. Integrated crop management approach through experience sharing, self-teaching and a hands-on technique is a tangible technology uptake pathway for recommended practices.

OFSP in Disaster Mitigation. James Arwata Foundation (JAF) with support from NARO, CIP, Senior Family Charity Foundation in the USA and PRAPACE has distributed OFSP planting material in the war ravaged districts and donated OFSP roots to resettlements camps in Northern Uganda where Joseph Kony operates.

The private sector engagement in OFSP. This has gaining momentum as highlighted below:

- 1) The number of farmers selling OFSP vines, roots, and processed products is increasing
- 2) Maganjo Grain millers markets a composite flour that has OFSP flour as an ingredient.
- 3) Ugachick conducted trials to use OFSP flour in their chicken feed.
- 4) Training of CBOs and farmer groups in production of sweetpotato products such as bread, doughnuts, chapatti has stimulated growth of small-scale enterprises in villages in peri-urban centers.
- 5) HORTEXA (Association of Horticultural Exporters) exports sweetpotatoes, including OFSP to Europe.

Conclusion

There has been rapid dissemination of OFSP in Uganda. The initial pilot OFSP project covered five zones in Luwero District in Central Uganda in late 2000. The participating farmers had no OFSP planting material to start with. A multi-sectoral approach involving partners from different organizations, NGOs, the private sector (such as processors), community based organizations, individual farmers and farmer groups worked together. The partners provided OFSP cultivars to conduct participatory evaluation of OFSP, sensitization of the communities regarding the widespread vitamin A deficiency in the country and need to grow, consume and commercialize OFSP to alleviate the deficiency and poverty. The number of partners increased and dissemination of OPSP from the single limited localized research pilot area of Luwero District in central Uganda accelerated, reaching at least 30 districts by 2003. Some of them districts were already selling OFSP vines, roots and processed products by the end of 2003. The different partners attribute this success of rapid dissemination of OFSP to active sustained involvement by the partners.

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Dissemination and commercialization of orange-fleshed sweetpotato varieties through FFS and VITAA partnership: Experiences from eastern Uganda

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Abstract. Integrated Sweetpotato Management through farmer field schools was incorporated into the already established IPPM FFS (Integrated Pest and Production Management Farmer Field Schools) programme in East Africa. It was aimed at promoting sustainable sweetpotato production and post harvest management. After four months field implementation of this technology-based and farmer education project, partnership was forged with the VITAA (Vitamin A Africa) initiative to disseminate and promote commercial production of orange-fleshed sweetpotato (OFSP) varieties. Since then a cumulative total of 1622 bags of vines each containing 1800-2400 cuttings ready for planting worth Uganda Shs 9,732,000 (US\$ 4866) have been distributed to farmers through farmer-oriented organizations within Soroti district. More than 600 bags of OFSP vines have been distributed to farmers through FFS and VITAA promoting partner organizations. Whereas the other partners reported complete crop failure due to the adverse weather conditions during the first crop cycle, 2 FFS managed to produce orange-fleshed roots for processing and delivered about 1 metric ton of chips to Maganjo processing factory in Kampala. Of an estimated total of 72 acres of OFSP planted during the second cycle, 20% of the planting material was supplied by the FFS vine bank

plots. Two sub-counties have prioritised sweetpotato as a commercial crop through the NAADS programme. CIP provided two chipper machines to FFS and other sweetpotato producer groups in a bid to transform sweetpotato into an industrial crop and is spearheading the search for linkages to find alternative markets for chips. Although the pilot venture into commercialization through processing did not appear to be profitable, the idea of selling OFSP to boarding schools and other institutions seems to be a more promising alternative market.

Introduction

Sweetpotato is grown as a food crop in many Sub-Saharan Africa countries and covers an estimated 2.1 million hectares with annual estimated production of 9.9 million tones of roots. It is the third most important food crop in east Africa and ranked seventh among the food crops produced in the world and has an annual production of 138 million metric tons (Edison, 2000). Uganda is the world's second largest producer of sweetpotato and first in Africa. Sweetpotato plays a primary role in food security in Uganda especially in the eastern region where two crops per year are grown for both home consumption and to supplement household income by sale to local

markets and urban centres. Although crop utilization in urban centers was previously limited and often kept secret as it was considered to reflect the low income status of the consumer, it is becoming increasingly important in urban food systems and there has been tremendous positive change in attitude towards the crop.

In spite, of the increasing popularity of sweetpotato in both rural and urban food systems, most local varieties grown throughout the region have white or cream-coloured flesh, and supply little or no pro vitamin A in the body (Draft Sweetpotato Technical manual, 2003). Vitamin A deficiency is one of the major health problems which most developing countries currently face. This micronutrient is critically deficient in the diets of the majority of people in the east African region especially in rural areas, particularly young children. Severe deficiency leads to night blindness, while less severe forms reduce a person's general health and capacity to fight off malaria, measles, diarrhea, AIDS associated illnesses, pneumonia and other diseases. Vitamin A deficiency has been identified as the leading cause of early childhood death and a major risk factor for pregnant and lactating mothers in East Africa (FAO/WHO, 1992).

Whereas Food and Agriculture Organization's (FAO) food balance sheet indicates an improving trend of Vitamin A in the diets for most developing countries in the last 20 years, in East Africa the overall vitamin A supply is actually decreasing (United Nations, 1992). According to International Food Policy Research Institute (IFPRI) projections 2000, the number of the malnourished children will continue to increase from 33 million in 1997 to somewhere between 39 and 49 million in 2020.

According to FAO/WHO report 1992, vitamin A intake is often inadequate because of the seasonality of food sources, the early abandonment of exclusive breast feeding, high morbidity levels, and practice of not giving vitamin A-rich food to young children. Dependence on capsules donations from

UNICEF and use of fortified foods is quite costly and not implemented widely. The best sources of beta-carotene are liver and fish-liver oils, which are very expensive for the rural poor. The best plant sources of beta-carotene, which the body turns into vitamin A as needed, are carrots, green vegetables and orange-fleshed sweetpotato (OFSP). Whereas most rural people especially in eastern Uganda associate carrots with rich families and greens are regarded as inferior vegetables to be used during periods of scarcity, sweetpotato is traditionally regarded a famine crop that can substitute for cassava and fits in many food mixtures (blends) and forms.

To date countries tackling the Vitamin A deficiency problem are focusing actions largely on a combined approach of supplementation as a curative measure, promoting the increased production and consumption of Vitamin A-rich foods, and use of fortified products. Beta-carotene (precursor of vitamin A) reported as units of vitamin A activity in many studies is the most prevalent source of vitamin A in our foods (Colgan, 1995), and thus, the introduction of Vitamin A-rich sweetpotato in farmer-oriented programmes can play an important role in improving their nutrition and is amenable to agriculturally-based interventions (FAO and WHO, 1992). The OFSP varieties, which have previously been relatively uncommon in Africa, are providing their worth as a low-cost, easily available, natural, dietary source of pro-vitamin A. The total carotenoid content of sweetpotato has been found to range from 0 to > 20 mg/100g of fresh weight depending on the variety (Akoroda and Teri, 1998). Sweetpotato has a comparative advantage over other common staple foods especially cereals and legumes which provide zero to minor traces of beta carotene equivalents. Children below 5 years, 7-10 and adults need to eat about 30, 40 and 80g of OFSP respectively, to meet the daily requirements of pro-vitamin A therefore even if OFSP is not a preferred diet for an individual consumer, one needs only a small portion in addition to

the preferred choice and farmers with small plots can adopt it as a back garden crop to supply roots and leaves for daily household dietary supplementations (Third Draft Technical Manual, 2003).

International Potato Center (CIP) is providing support towards modern technological dissemination to improve on production, post-harvest handling and processing to add value (Tara, 2003). This would improve on the current fragile food security, low per capita income, and very low availability of Vitamin A in the diets, which according to the United Nations report 1992, Vitamin A supply in the East African region is actually decreasing due to seasonality of food sources, early abandonment of exclusive breast feeding and high morbidity levels. In recent years, technology dissemination through Farmer Field Schools (FFS) has been introduced to East Africa and is seen as a promising approach for sustainable technology adoption. Participatory systems approach is well suited to increasing rural incomes because they are tailored to the requirements of the villagers and build on the strengths and knowledge of the smallholder community (Chandra, 2000). Therefore, piloting promotion of OFSP activities through the recently started sweetpotato integrated pest and production management farmer field schools (SP IPPM FFS) groups set up as part of the UK Department for International Developments (DFID) Crop Protection Programme funded project 'Promotion of sustainable sweetpotato production and post-harvest management through farmer field schools in East Africa' would strengthen dissemination and technology uptake among farmers and other end users.

World Health Organisation (WHO) estimates that in many of the under developed and developed countries, several nutritional disorders are prevalent, and could easily be alleviated by consuming root and tuber crops like sweetpotato (Edison, 2000). According to VITAA Newsletter (2001), the Vitamin A for Africa (VITAA) partnership is promoting consumption, production and marketing of

OFSP varieties which have been lacking in the traditional farming systems. The partnership is extending the impact of OFSP varieties through community awareness of nutritional benefits. International Potato Center in collaboration with Soroti district agricultural extension agencies/National Agricultural Advisory Services (NAADS), research institutions, community-based organization such as Soroti Catholic Diocese Development Organisation (SOCADIDO), World Vision launched as an immediate action plan for establishment of OFSP varieties by facilitating distribution of planting material and awareness raising about vitamin A deficiency to potential sweetpotato farming communities. Since the launching of OFSP in Gweri sub-county in September 2002, CIP has continued to support sensitization seminars, workshops, radio talk shows and press articles involving a cross section of stakeholders. International Potato Center (CIP) facilitates the provision and delivery of planting material for commercialisation and evaluation, and is spearheading the promotion of OFSP as an industrial crop by encouraging processing and searching for viable market options.

Farmer Field Schools (FFS) are an effective and popular method of farmer education in which learning is through discovery and adoption. Farmer Field Schools have been found to be a successful technology dissemination approach in a number of countries including Indonesia, Sudan, Benin, Ethiopia and East Africa Federation (M'Boob, 2002) they facilitate increased farmer understanding of crop ecology and farmer experimentation combining and comparing indigenous and researcher developed technologies that allow farmers to evaluate and develop appropriate pre and post harvest crop management strategies for their specific farm conditions and needs. Farmer Field Schools have become popular entry point for most agriculturally -oriented programmes in Uganda including NAADS and Acquired Immunity Disease Syndrome (AIDS) Awareness activities. Technical staff in the traditional extension service or graduates of

previous FFS are contracted to facilitate the FFS throughout the cultivation season.

Participants are led through the growth and development stages of both the above and underground plant parts by using a hands on approach, or inciting leading to discovery and action. The language of guidance or instruction is preferably indigenous. Group dynamic exercises enhance togetherness and their sub-group session rotation as hosts, computation and result presentation leads to expression of their value of togetherness, mission understanding and leadership challenges. This has been manifested in a number of FFS graduates from previous Integrated Pest and Production Management (IPPM) FFS being elected to responsible positions within the community leadership councils, and the evolving of farmer facilitators' association with the aim of competing for provision of selected community services.

Inclusion of OFSP variety growth and performance assessment in FFS learning and commercial plots enhanced their dissemination and highlighted their nutritional importance. Participants sensitized on the use of OFSP, multiply varieties that have already passed consumer acceptance tests, evaluate agronomic performance of candidate accessions, produce OFSP roots for commercialisation, process OFSP for commercialization and grow them side by side in their own fields. Achievement days during which the community and influential people are invited are held to display the activities done during the season. Therefore the objectives of the partnership were to: 1) promote sweetpotato integrated field crop and post harvest management; 2) make orange-fleshed sweetpotato available on large-scale, demonstrating the potential of crop-based approaches in alleviating micro-nutrient deficiencies; 3) promote commercialisation through processing and utilization.

Strategies used for promoting OFSP varieties

Linking farmers to market. A meeting on linking sweetpotato farmers to markets was held on 5th Sept 2002 at SOCADIDO, Soroti chaired by Father Martin Aeho and attended by the marketing manager of Maganjo Grain Millers; sweetpotato farmers from potential sweetpotato growing areas in Soroti district, community development organizations (SOCADIDO and World Vision), researchers involved in sweetpotato improvement and post-harvest programmes, agricultural field extension workers, the CIP regional breeder, the SP IPPM FFS project assistant, and nutritionists. The goal of the meeting was to promote the socio-economic development of OFSP farmers and processors through integration of production, processing and marketing thereby linking a wide range of public and private sector institutions. During the meeting community-based organisations and farmers emphasised the lack of market as the most important limiting factor for large scale production because farmers tend to avoid excess root harvest for fear that they would not be able to dispose of them while in contrast processors represented by Maganjo Grain Millers singled out lack of chips from sweetpotato producers as a factor delaying effective inclusion of sweetpotato in their composite flour mixtures. Therefore strategies developed to promote both production and processing included: a) acquisition of vine stocks from central region, establishment of rapid multiplication plots and swamp nurseries to buffer up supply especially for immediate planting after prolonged dry seasons were components sighted for sustaining the seed systems in Soroti and Kumi; b) establishment of a sustainable rural-based sweetpotato processing enterprise to supply quality dried chips to identified market opportunities. CIP/PRAPACE pledged to provide two processing machines for the two groups that would be

identified as potential processors; c) identification of contract farmers to multiply seed vine of Ejumula, Kakamega and Naspot 5 orange-fleshed varieties for distribution to other farmers; d) a field day was planned to be held at Gweri sub-county as a central and potential sweetpotato growing area to sensitize the community on combating vitamin A deficiency and promote on-farm production of sweetpotato for home consumption and market.

The viability of commercializing production of OFSP varieties was estimated by assessing the expected production costs and compared with the processors' price offers. It was observed that during slack

seasons leading to limited root supply, processing was not profitable because the open markets would offer better prices for roots. However, participants noted the viability of piloting orange-fleshed processing as a first step towards promoting industrialisation of sweetpotato and stimulating increased production. Costs and profits at different levels of sweetpotato production and processing were estimated and indicated that commercial processing was not economical (Table 1).

Field day to launch OFSP varieties. Promotion activities for OFSP varieties launched at Gweri sub-county in Soroti, eastern Uganda in 200.

Table 1: Costs for processing 100 kg of dried sweet potato chips using powered chipper and raised tray dryers.

Item/activity	Details	Quantity	Unit price (US\$.)	Sub total (US\$.)
Fresh tubers	Farm gate price	3 bags (320kg)	4.00	9.00
	Peeling 3 bags	6 pers @ 4.5 hrs	0.13/pers/hr	3.38
	Washing	3 pers. @ 6 hrs	0.13/pers./hr	2.25
	Water	6 jerry cans (120 lts)	0.03/jerry	0.15
Slicing	Labour	2 pers.	0.13/hr/pers.	0.13
	Fuel	0.5 litres	0.70	0.35
	Oil	0.5 litres	0.50	0.25
Drying	Labour	2 pers./1.5 days	0.40/pers./day	1.20
Packing	Gunny bags	1	0.25	0.25
	Inner polythene	1	0.25	0.25
Transport	To Maganjo	100 kgs	0.01/kg	1.00
Total processing cost	Slicing, drying and delivery of to factory	3 bags of fresh roots (320 kgs)	6.07/bag	18.21
Production cost of dried chips	3.2 kgs fresh roots = 1 kg dry chips	100 kg	0.18	18.00
Factory price/kg chips	1 kg of dry chips delivered at factory	1 kg	0.18	0.18
Gross income	Sale of chips	100	0.18	18.00
Net profit	3 bags of fresh tubers or 100 kgs chips			0

The CIP regional breeder highlighted the efforts being taken by different partners and the importance of OFSP program for combating Vitamin A deficiency. During the function the VITAA Coordinator reported that the occasion was part of a series of planned promotional activities to be held in the country and other parts of Africa through the VITAA initiative. Success stories associated with OFSP cultivation and use in the central region of Uganda were shared with other participants. Demonstrations were carried out on sweetpotato production and processing and exhibition of sweetpotato products such porridge, and processed flour from Maganjo processing factory were displayed. Some planting materials of OFSP were also distributed.

Public and farmer - awareness seminars, talks, workshops. The district policy making body urged councilors to advocate for consumption of OFSP varieties. They also pledged to encourage educational boarding institutions to include OFSP in their weekly menus. Radio talk shows involving policy stakeholders were organized to promote production, consumption and marketing of OFSP varieties. During technical review workshops OFSP was highlighted as a cost-effective nutritional strategy for the majority of rural people. One commonly highlighted issue during the meetings was the comparison

of vitamin A levels in common staple foods and the vitamin A requirements (Table 4) which served as evidence to help justify the adoption of OFSP into the production systems and dietary habits.

Provision of the most limiting inputs. International Potato Center (CIP) in liaison with National Agricultural Organisation (NARO) and district farmer-oriented organizations namely NAADS and SOCADIDO facilitated the supply of OFSP planting material and two chipper machines on credit for pilot processing.

Promotion of production and post-harvesting technologies. Two pilots SP IPPM FFS with a total of 60 participants successfully completed the first field season in July 2003. A field day was held and OFSP products (doughnuts, pancakes, chapattis, cakes, crisps and chips) exhibited. These products sold off very fast and stimulated the demand for vines of these varieties and the scaling up of the project to a wider section of the community coverage. Therefore, 4 sweetpotato farmer field graduates who excelled during the first pilot cycle were selected for a week-long induction skills empowerment training at Namuloge Research Station so that they could boost the 2 extension-led facilitators and the number of could then be tripled during the second pilot cycle.

Table 2: Vitamin A levels (average per 100g edible portion) in common foods in East Africa.

Source	Form [Beta carotene equivalent (g)]						
	Fresh	Boil	Skin boil	Dried	Porridge	Bread	Leaves
Sweet potato	0-20,000		0-20,000	7,820			2,700
Cassava		0-20					8,280
Fresh maize		240					
Maize flour					0	0	
Rice		0					
Beans		Trace					
Carrots	12,000						
Tomato	600						
Cabbage		Trace					Trace

Table 3: Root flesh colour of sweet potato related to dietary supply of vitamin A

Age/sex	Vitamin A requirement (µg RE)	Amount (g) of fresh sweet potato roots required to supply the daily requirements of pro-vitamin A			
		Araka (white)	Osukut (yellow)	Kakamega (orange)	Ejumula (deep orange)
1 day-3 years	400	3636	265	78	35
4 to 6 years	500	4545	331	97	43
7 to 10 years	700	6364	463	136	61
Females over 10 years	500- 850	7273	530	156	69
Males over 10 years	500- 600	9091	662	194	87

Source: (Technical Manual, 2003).

Production profile of OFSP. Inspite of the poor weather conditions (drought) during the first pilot season the SP IPPM FFS participants managed to produce and supply OFSP roots for processing and conserved vines for subsequent season otherwise the non-FFS growers lost all their crop. Total OFSP acreage increased from 10 acres during first season to over 70 acres in the second cycle. About 10 tons of OFSP chips were produced by FFS in the first and second cycles respectively.

Promotion of processing and marketing. To kick-start the processing and marketing of chips, the NARO post-harvest programme extended a revolving fund to processors to pay for the roots and meet the costs involved in processing and transportation of dried chips to Maganjo flour milling factory. Continued efforts have been directed towards attracting alternative markets for dried chips such as Kirinyaga millers in Nairobi, Kenya and Ugachick poultry feed producers in Uganda. Maganjo flour products are available in most Supper Markets in Uganda. Preparation and utilization of various recipes is being encouraged through FFS.

Field achievement day. A joint field day organized by SP IPPM FFS project and Abuket Oyuunai Sweetpotato Processors to appraise the activities of farmer field school activities was held at Okunguro Farmer Field Schools (FFS) and attended by a cross section

of stakeholders. The event was officiated by the Local Council V (LCV) Chairman, the highest policy making organisation in the district. Field guided tours and demonstrations were conducted to explain the improved field production technologies, commercial sweetpotato chipping and preparation of various OFSP recipes were demonstrated and exhibited for sale. Local songs and a poem were sang and recited to express the usefulness of the SP IPPM FFS project.

Achievements - The partnership made the following achievements:

- Rapid dissemination increased production and consumption of OFSP varieties,
- Farmers appreciation of the commercial potential of sweetpotato and the successful linkage of primary processors to flour millers,
- Intra-institutional participation in promotion of OFSP varieties,
- Inclusion of sweetpotato on the priority list of Gweri and Kyere subcounties, and subsequent approval of funding by NAADS.

Lessons learnt by promoters and farmers

- Commercialisation through processing did not seem to be profitable while the sale of OFSP roots to boarding schools appeared

more promising. Further promotional strategies are being geared towards increased food processing and local fresh root consumption. It is important for food processors to focus at flour mixtures for both the medium class and traditional rural

markets whose stocks often run out during prolonged post-harvest seasons.

- Whereas farmers recognize that their production approaches result in low yields, they avoid opportunities that

Table 4: Institution responsibilities and significance of linkage to promotion process.

Institution(s)	Responsibilities	Importance of promotion process
NARO	Provision of basic seed and training in production techniques and post harvest handling	Availability of improved clean seed, product utilization /acceptability & technology empowerment
SOCADIDO/ World Vision	Seed distribution to communities and farmer group formation	Household food security, wide dissemination and adoption in every household in the communities, wide seed distribution
CIP	Provision of advanced clones and technical support	Variety dissemination, adoption and utilization/ acceptability & sustainability
SP IPPM FFS project (Global IPM Facility, CIP, NRI, NARO, KARI)	Project development for SP IPPM FFS, sourcing funds for FFS activities, project implementation, reporting, M&E, dissemination, mirror activities in W. Kenya & W. Tanzania	Implementation (Set up, fund, support and monitor all SP IPPM FFS activities and plan scaling up)
PRAPACE	Technical support	Market orientation and technology adoption
NAADS/DAO	Enhanced variety and technology dissemination and adoption	Modernisation of agriculture (Food and poverty alleviation)
Farmer groups	Field and post harvest evaluation, proper management and commercial production	Enhanced production, processing and marketing skills
COARD	Training farmers in seed multiplication, conservation and quality chip production	Enhanced production, processing and marketing techniques at farmer level. Training farmers in clean seed production and conservation, and quality chip production
Flour millers	Flour processing	Value addition and creating vertical sweet potato marketing
Policy makers	Sensitisation and project activities backing	Increased adoption, acceptability and approval of scaling up
Educational institutions	Provision of market and in-depth sensitization	Sustainable wide utilization multiple dissemination and adoption

result in excess harvests that may not be disposed off. The marketing opportunities being created for OFSP have enhanced technology up-take because farmers want to take advantage of presumed profitable opportunities.

- Orange-fleshed sweetpotato chips have poor mashing characteristics during local dish preparations (Atap). This may lead to their poor adoption. However, processing OFSP into other products may encourage farmers to adopt them.
- Embracing Extension officers from the existing traditional service is a disincentive to technology dissemination and adoption unless they are closely supervised. Farmer facilitators, with a good grasp of the technologies and approach were found to lead to better learning by the FFS.
- Rallying local stakeholder support speeds up the process of promotion and dissemination.
- Machine-sliced chips are not easily affected by storage weevils as compared to traditional manual slicing method.
- Commodity market potential is a crucial sustaining ingredient of technology reception and adoption.

Discussion

Although significant progress has been made towards promoting production, processing and consumption of OFSP varieties, there is a general need to search for more competitive markets for both roots and chips. Existing opportunities such as exportation of organic fresh roots to European Union countries avenues to supply local markets should be explored. Farmers are also encouraged to stagger their planting periods to avoid over supply during peak harvest seasons.

Research should among other tasks develop varieties that fit the traditional cooking and eating qualities of white-fleshed roots. Farmers/consumers have already reported problems with the poor fragmentation of boiled orange-fleshed chips during preparation of local dishes. Processors could investigate the potential for packing sweetpotato-cassava composite flours to increase their shelf-life so that it can be supplied to Super Markets and local shops. This would increase the level of use of OFSP flour as most potential consumers would like to avoid laborious processes of preparing local foods. OFSP varieties especially the most popular Ejumula is highly susceptible to viral infections implying that they cannot be recycled for more than three generations. Therefore arrangements should be made to replenish them with clean vines periodically.

Collective appraisal of the of approaches used by different stakeholders would probably lead to wider appreciation and advocacy for institutionalization of the FFS approach among different stakeholders both as a technology and input-based approach for agricultural-oriented communities.

Conclusions and Recommendations

- Orange-fleshed sweetpotato promotion through SP IPPM FFS has resulted in fast and effective dissemination and adoption of IPPM sweetpotato technologies.
- More initiatives are needed to widen the market opportunities and improve on prices.
- Research should focus at improving disease resistance, especially viruses and dry matter content of OFSP varieties. Opportunities to conserve vines during dry season should be encouraged to avoid continuous purchases of vines from the central region where the virus pressure is much higher.

- Follow-ups on FFS graduates and increased support to backstopping the farmer-facilitators through the farmer facilitators association to establish a sustainable technology dissemination system.
 - Policy makers should spearhead the institutionalization of the FFS approach
 - Farmer processors chipping roots should explore opportunities of acquiring soft loans from community-based credit institutions.
 - Millers should aim at composite formulations for both local and foreign markets.
 - Further sensitization on quality maintenance especially of grated products.
 - Scaling up dissemination of OFSP varieties within and outside Soroti district.
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Development and promotion of sweetpotato products in Western Kenya

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Abstract. Sweetpotato utilization in western Kenya has for along time been limited to boiling, roasting and chewing raw. In order to add value to the crop, attempts have been made to process sweetpotato into different products. Several products were prepared among them ‘crackies’, ‘*mushenye*’ Amaranthus relish with sweetpotato flavour and sweet potato juice. These products were evaluated by extension agents for acceptability. The most highly ranked products were ‘crackies’ made from sweetpotato and cassava flour, ‘*mushenye*’ made from sweetpotato variety *Mugande* and juice from the orange-fleshed sweetpotato variety SPK004. Amaranthus relish with sweetpotato flavour was more preferred to amaranthus with Roiko or soya flour flavour. The study also showed that products with a combination of sweetpotato and cassava flour were more preferred to pure wheat products. Currently the selected products are promoted through field days, shows as well as individual and group training involving different technology transfer agents such as NGOs and community based organizations. The study showed there is high potential for sweetpotato products utilization in home consumption.

Introduction

Sweetpotato (s/p) is the world’s seventh most important food crop after, wheat, rice, maize, potato, barley, and cassava (CIP 1996). Domestic supply through production of sweet potatoes indicates that it is third besides

maize and cassava in calorie output (FAO 1992-94). It is an important staple food in Kenya, utilized by most households and as described by Hagenimana *et al* it is a woman’s crop and available all year round (Hagenimana *et al.*,1999). Therefore sweetpotato has the potential of bridging the food gap due to diversified processing and utilization technologies that have been produced but not yet fully exploited. The color intensity of the sweetpotato root flesh differs from one cultivar to another and varies from white to deep orange. The intensity of the color is attributed to carotenoid content (Ameny and Wilson 1997). A study on carotenoid content in fresh, dried and processed sweetpotato showed that increased consumption of orange flesh sweetpotato in either fresh or processed form can contribute in alleviating dietary deficiency of vitamin A (Hagenimana *et al.*,1998) Consumption of sweetpotato in Western Kenya is mainly in raw, boiled or roasted. Storage practiced is in-ground and only harvested when need for consumption or sale arises. The International Potato Center (CIP) and Kenya Agricultural Research Institute (KARI) developed technologies using sweetpotato in three forms, (boiled and mashed), (grated) and (flour, mixed with 30% to 50 % wheat flour) these were acceptable to consumers. However recent survey indicates that the products were expensive due to inclusion of wheat flour. This paper describes development and promotion of cheaper products by replacing wheat flour with cassava flour. Consumers also requested skills in juice and spicy food additives.

Products were made, tested and evaluated for general acceptability. The best options were selected, improved, tested and evaluated again and then replicated on-farm. Data was collected and analyzed and most acceptable products transferred to farmer groups and extension agents through demonstrations. Groups and individuals interested in micro enterprise were given skills in simple product making, packaging and promotion.

Materials and Methods

Ideas concerning improvement of old products and new products were generated and tried out at KARI laboratory. Participatory interactive methods were used to transfer skills in product production and promotion to extension, farmer groups and , Non Governmental Organizations (NGOs)/ Community Based Organizations (CBOs) agents. This study was done on the following products: juice, mshenye, crisps, crackies, chapatti, mandazi, onion bites and sweetpotato flavour.

Fresh sweetpotato juice made from three sp varieties (SPK 004 orange flesh and high in Vitamin A, Mugande white flesh and liked for marketability and Bungoma cream flesh and popular with farmers). The roots 600g of each variety were peeled, washed, boiled and mashed. For each variety, 500g of mash and 2000ml of water were mixed and sieved. The result content for each variety was 1800ml and divided in three for the following treatments:

SPK004 plain
SPK004 + sugar
SPK004 + sugar + lemon juice
Bungoma plain
Bungoma + sugar
Bungoma + sugar + lemon juice
Mugande plain
Mugande + sugar
Mugande + sugar + lemon juice

Test panel at KARI lab evaluated and eliminated the first two treatments for each variety and recommended the last treatment

for each variety for on-farm test. Farmer groups and extension staff carried out on-farm tests.

S/p crisps. 18 medium roots from three varieties of sweetpotato (SPK 004, Mugande and Bungoma) were washed, peeled, washed again and sliced into very thin pieces using a kitchen grater. The contents were separately put in salted water, drained and deep fried till starting to brown. The crisps were removed from oil, salted and let to cool. The crisps were tested, evaluated and recommended for on-farm tests, which were done.

S/p “mshenye”. 9 medium roots from three varieties (SPK 004, Mugande and Bungoma) were washed, peeled, washed again, sliced and boiled. 600g of pre-boiled maize and beans was divided in three portions of 200g and added to each variety of sweetpotatoes and mashed. Salt was added to taste and the product tested and evaluated for variety and recommended for on-farm tests.

S/p Crackies. Wheat flour (Unga Millers Ltd. Nairobi) 400g and soya flour 50g for crackie1, S/P flour 200g, wheat flour 200g and soya flour 50g for crackie2, S/P flour 150g, cassava flour 250g and soya flour 50g for crackie3 was weighed and put in three mixing bowls. Baking powder (Kapa Oil Refineries) 10g and cayenne pepper 10g (Ruby Industries - Nakuru) were sieved into the flour, iodized salt 3g (Kensalt Nairobi) was sprinkled on each mixture. Bahari oil 20g (Bidco Oil Refineries Ltd. Thika) were added. Rub-in method was used to mix the ingredients. An egg was broken, poured in a cup, checked, and then added to the mix. A cooking stick was used for a while to turn in the egg then rub-in method resumed. A little warm water was added to soften the dough. Kneading was done by hand till the required texture of elastic smooth dough was formed. The dough was left to relax while cooking oil was poured into a pan and put on the Kenya Ceramic Jiko (KCJ) to heat. The dough was packed into the noodle machine and the handle of the machine turned clockwise to

extrude the contents. The dough contents were dropped into the hot oil and let to brown while turning with a perforated flat long spoon. After attaining golden brown color, the contents were removed and drained put in plastic buckets and left to cool, tested, evaluated and recommended for on-farm.

S/p chapati Wheat flour 400g and soya flour 50g for chapatti 1, S/P flour 200g, wheat flour 200g and Soya flour 50g for chapatti 2,. S/P flour 150g, cassava flour 250g and soya flour 50g for chapatti 3 was weighed and put in three mixing bowls. 50g of oil and 5g of salt were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowls and kneaded till stiff smooth paste was formed. The dough was divided into 8 equal balls and rolled on a floured surface. Each ball was folded to form a strip and coiled to form a circle and put aside for 20 minutes. Each coil was rolled out into a thin circular sheet and shallow fried on both sides till golden brown. The product chapatti, was tested, evaluated and recommended for on-farm.

S/p mandazi. Wheat flour 400g and soya flour 50g for mandazi 1, S/P flour 200g, wheat flour 200g and soyafLOUR 50g for mandazi 2,, S/P flour 150g, cassava flour 250g and soya flour 50g for mandazi 3 was weighed and put in three mixing bowls. 20g of oil, 40g sugar and 10g of baking powder were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowl s and kneaded till smooth paste was formed. The dough was rolled on a floured surface to 1cm thickness. A knife was used to cut uniform square pieces, which were deep fried till golden brown. The mandazi products, were removed from oil, drained, cooled, tested, evaluated and recommended for on-farm.

S/p onion bites. Wheat flour 400g and soya flour 50g for onion bites1, S/P flour 200g, wheat flour 200g and soyafLOUR 50g for onion bites 2,, S/P flour 150g, cassava flour 250g and soya flour 50g for onion bites 3 was

weighed and put in three mixing bowls. 20g of oil, 10g salt, 5g of chilli powder, 10g chopped spring onion and 10g of baking powder were added to the flour and mixed well. Lukewarm water was added to the mixture in the bowl s and kneaded till a soft smooth paste was formed. The dough was cut into small balls that were deep fried till golden brown. The products were removed from oil drained, cooled, tested, evaluated and recommended for on-farm.

Sweetpotato flavour was made by extracting 300g starch from white sweetpotato roots. The starch was divided into three portions of 100g and given three treatments as follows: **1.** Spices 70g, Sugar 20g, salt 10g, **2.** Spices 40g, Sugar 40g, salt 10g, **3.**Spices 20g, Sugar 60g, Salt 10g. The spices were added to amaranthus relish, tested and evaluated. The first and third were eliminated and recommendation given to use the second lot. The selected lot was taken on-farm and compared with soya flour and roiko mix which is a commercial flavour

Promotions. Product testing and promotion was done through several channels as follows:On-farm demonstrations and trainings to farmer groups, NGOs/CBOs, displays, tasting/lectures at agricultural shows, schools, farmer field days and on- site training to Ministry of Agriculture extension.

Results and Discussions

The sugar and lemon juice addition in the sweetpotato juice made the product highly acceptable as compared to when the product was plain or only sugar was added (Table 1). The evaluators compared juices with three commercial varieties of 'Fanta' soft drink. The test of SPK004 was likened to 'Fanta' orange, Bungoma to 'Fanta' passion and Mugande to 'Fanta' citrus.

Overall SPK 004 variety was more preferred in the products than the Mugande and Bungoma variety (Table 2). The colour of SPK004 made the juice more appealing than

Mugande and Bungoma. The high dry matter content in the Bungoma variety and its yellow colour made it more popular for crisps. The Bungoma crisps were firm while the SPK004 were brittle. Mugande had highest sugar content which made it ideal for the *mshenye*. The second treatment of sweetpotato, wheat and soya is generally more preferred than the other two (Table 3). Chapati, mandazi and

onion bites required wheat flour this is due to the their soft texture. Crackies have entered the snack market in all districts involved in s/p activities due to the long shelf life of four months as compared to the other three that have shorter shelf life of three to four days. Sweetpotato flavour was comparably well accepted like the commercial roiko.

Conclusion and way forward

Products produced and promoted were well accepted showing that sweetpotato has a potential for substituting wheat in high percentages. Diversified sweetpotato utilization has an indication for improving food security and local household incomes of the region.

Markets and machines are identified and farmers informed. Collaborators like NGOs are involved with farmer mobilization and machines acquisition and this is intended to help expand production and utilization of sweetpotato products.

Table 1: KARI panel fresh sweetpotato juice acceptability evaluation (N=20).

SPK004 plain	-
SPK004 + sugar	1
SPK004 + sugar + lemon juice	19
Bungoma plain	-
Bungoma + sugar	1
Bungoma + sugar + lemon juice	19
Mugande plain	-
Mugande + sugar	1
Mugande + sugar + lemon juice	19

Table 2: On-farm acceptability of products made from three varieties of roots (N=30).

Products	SPK 004	Mugande	Bungoma
Juice	20	5	5
Mshenye	10	15	5
Crisps	2	5	18

Table 3: On-farm acceptability of products made from combinations of flour (N=30).

Products	Wheat+ soya	S/P+wheat+soya	S/P+cassava +soya
Crackies	1	10	19
Chapati	8	18	4
Mandazi	10	14	6
Onion bites	4	16	10

Table 4. On-farm acceptability of sweetpotato flavour (N=30).

S/p flavour	12
Roiko	13
Soya flour	5

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Orange-fleshed sweetpotato as a disaster mitigation crop in war- torn Northern Uganda

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Abstract. In the war-torn northern Uganda, the regional potato and sweetpotato Improvement Network for East and Central Africa (PRAPACE), the International Potato Centre (CIP) and the National Agricultural Research Organization (NARO) worked with the James Arwata Foundation (JAF), a local NGO initiated in 2002, and other partners to mitigate war-related famine that is threatening about 53,000 internally displaced households. For this noble collaborative effort, orange-fleshed sweetpotato varieties Kakamega and Ejumula were used to provide the much-needed vitamin A and bolster food security in the region. Sweetpotato proved to be an effective famine mitigating crop in war- torn areas and the intervention supplied about 60 tons of food (roots) to internally displaced people living in camps in Apac, Lira and Gulu districts. Participating local farmers earned over US\$12,000 from sale of vines within a short period in 2002. This paper therefore narrates experiences with people in war- torn northern Uganda, and analyses the potential of sweetpotato to mitigate disasters.

Introduction

Northern Uganda has been a central stage of insurgency for almost two decades now; a calamity that has left over one million people displaced and living in protected camps. Due to security concerns internally displaced people (IDP) cannot attend to their farms except for a few hours each day, when there is

assured security. This restricted opportunity for the IDP to work and the displacement itself has resulted in serious food and income shortages. Government in collaboration with other relief agencies has responded by providing food relief directly to the affected families. Most often, the food supplies are inadequate in meeting daily dietary requirements and some times they are cut off due to lack of safe passage to camps because of sporadic outbreaks of fighting. To cope with the food scarcity situations, people particularly women, have always risked their lives and sneaked out of the camps to work in their fields.

Sweetpotato is an established part of the diet of rural people at risk (Tanganik *et al.*, 1998) of Vitamin A deficiency, particularly children. It is grown in areas where other sources of vitamin A, Such as oil palm and carrots are not common. Sweetpotato also plays a key role for households disrupted by HIV/AIDS and other crises (Andrade and Ricardo, 2002; Andrade and Ricardo, 2003). In northern Uganda, sweetpotato has been preferred because, among others, farmers know that it is hardy enough to thrive under rugged conditions easy to establish, requires no or minimum care and produces sufficient quantities of food for the household in a short time of about 3-4 months. Farmers have also realized that unlike cassava sweetpotato is not easily looted by the roaming hungry rebels. Introducing orange-fleshed sweetpotato varieties provided an extra

opportunity of fighting vitamin A related malnutrition among the war-affected persons in Northern Uganda (Kapinga *et al.*, 2003). This paper therefore analyses the potentials and opportunities of sweetpotato, particularly orange-fleshed types in mitigating famine and malnutrition rife in war affected communities of northern Uganda. It narrates experiences of using orange-fleshed sweetpotatoes to feed war-affected people in Northern Uganda.

About James Arwata Foundation (JAF).

Initiated in early 2002, JAF is a community-based organization that aims at transforming human mind for improving socio-economic living conditions of the marginalized groups to avert feelings of apathy. Acting as a civil society organization, JAF gives light direction and links marginalized groups to various innovations or appropriate technologies, markets, and other service delivering national and international organizations. It has worked for marginalized and resource poor farmers in the war-torn districts of Apac, Lira, Gulu, and Pader. JAF was initiated with the goal of improving food security, nutrition and income of the community in war-torn areas.

Approach

JAF on its own has been able to mobilise and sensitize different farmer groups on the multiplication, production and consumption of orange-fleshed sweetpotato. It has sourced and distributed planting materials to people taking into account of the security situations. For example, at the peak of insecurity JAF devised a method of dropping planting materials on strategic locations for farmers to access when sneaking back to their fields. Additionally, through establishing viable linkages (Tanganik *et al.*, 1998) to other organisations, JAF has been able to register early successes of using orange-fleshed sweetpotato as a disaster mitigant in northern Uganda. PRAPACE, CIP and NARO provided technical guidance and funds at different stages of the activities. The funds for purchase of the initial planting materials and

facilitation of training of JAF farmers and extensionists were provided by CIP and PRAPACE. CIP also provided additional funds to purchase a motorised sweetpotato chipper to process sweetpotatoes in the event of surplus production. NARO's sweetpotato program mobilised initial planting material among the commercial planting material multipliers in central Uganda. NARO also conducted trainings for JAF lead farmers and extensionists. At the grassroots JAF linked very well with the administration of respective districts and was able to utilise government extension personnel in some activities. Later on during distribution of the sweetpotato roots to the displaced people, JAF forged more linkages with stakeholders concerned with relief food distribution to people in the camps. Among the key linkages were those made to the district administration, Red Cross-Uganda, UNICEF and World Vision International. These provided transport for the mobilised sweetpotato roots to the people in the camps as well as distributing roots to the affected people.

Multiplication and distribution of sweetpotatoes in the northern Uganda.

JAF's involvement in promoting OFSP started in June 2002 with mobilization and sensitization of farmer groups in Apac on importance of orange-fleshed sweetpotato varieties. This was at time when this region was relatively peaceful. This fed into follow up planning meetings with farmer groups that led into forming farmer groups for multiplication, and eventually land preparation. By the second week of July, the first batch of planting material was delivered from Central Uganda. This was followed subsequently by the second and third batch deliveries. A total of 355 bags with estimated 851400 vine cuttings sufficient to plant 28.4 hectares was delivered (Table 1). Using additional funds from CIP, more 100 bags of vines were also delivered and distributed in Apac and Lira during 2003. All the planting material delivered in 2002 was of the variety SPK004 (Kakamega), while in 2003 it was only the variety Ejumula. SPK 004 is an

Table 1: Sources and estimates of planting material acquired by James Arwata Foundation in Northern Uganda, 2002.

Year	Source	Variety	No. of bags	Estimated No. of cuttings	Estimated area (ha)
2002	Luwero Farmers	SPK 004	305	732,600	24.42
	Kampala farmers	SPK 004	50	118,800	3.96
2003	Luwero Farmers	Ejumula	100	240,000	8.0
Totals			455	1,091,400	36.4

introduced orange-fleshed sweetpotato variety from Kenya (Mwanga *et al.*, 2004) that has proven to be high yielding, with high dry matter content, adaptable, and found acceptable in other parts of Uganda. Ejumula on other hand is a local variety that has been highly accepted across Uganda. It is deeper orange than SPK 004, has stable yields and with high dry matter levels (Mwanga *et al.*, 2004).

The first three batches of planting materials largely of SPK were distributed to three farmer groups, two in Lolo Sub County and one in Inomo Sub County all in Apac district. These groups served the dual purpose of multiplying vines and producing the first crop of sweetpotato that was harvested in December 2002. The batch that was delivered in 2003, was largely Ejumula and was spread to more groups. Apart from Lolo and Inomo in Apac, Ejumula was distributed to two more groups in Aduku and Bala sub counties in Apac district and one group in Lira district.

Scaling up of planting material deployment.

It is important to note that all the starter planting material purchased from central Uganda (Table 1) would not have met farmers' demand even if it were delivered as a single batch. A lot of farmers got interested and opened big fields after being mobilized and sensitized by JAF. This meant that the fields, which were planted using the very first batch of the material served as multiplication fields. As early as mid August vine cuttings were ready for distribution to other farmers within

and outside the initial groups. Table 2 shows the documented planting material that had been distributed to other farmers within and outside the initial target districts by JAF by March 2003. In the event that Apac and Lira districts became insecure during the last quarter of 2003, the distributions targeted the war-affected communities, including the war hot spots areas of Gulu and Pader districts. An estimated total of over 4.5 million vine cuttings covering an estimated total area of 151.5 ha have been distributed in the Northern region through JAF coordinated activities. The major beneficiaries have been Apac and Lira where the organization is largely based; a total of over 2.5 million vine cuttings have been distributed in the two districts. This is probably because the organization is based in the two districts, but probably also that the two districts were at the start of the multiplication and distribution activities were relatively peaceful. The activities were affected later when rebels infiltrated Apac and Lira districts. The second major beneficiary was Soroti district courtesy of the government NAADS program. JAF mobilized up to 640 bags of vines among its farmers and delivered then to Soroti. This consignment was estimated to have contained over 1.5 million cuttings and was estimated to have planted up to 51 hectares of sweetpotato fields. In total JAF farmers got Shs 3,840,000 (equivalent US\$ 1930) from sale of planting material.

Other districts like Pader and Gulu are war-hot spots and this probably accounts for the limited distribution of planting materials. This

shows, however, that there is great interest and demand in such areas, despite the difficulties farming communities are going through.

In general the expanded distribution of orange-fleshed sweetpotato planting material has enabled extensive coverage of the vines in the region more so in Apac and Lira districts. Table 3 shows some of the farmer groups that are known to have benefited from scaled up vine cuttings distribution activities. A minimum of 19 farmer groups has directly received planting material from JAF. However a lot more groups have benefited. For example, the number of NAADS groups in Soroti that finally received the planting material remained

unknown to JAF. But also there is a lot more planting material that has exchanged hands among farmers without getting to JAF's notice.

Orange-fleshed sweetpotato as a relief food in northern Uganda. Apart from acting as multiplication fields, the initial planted fields yielded a lot of sweetpotato roots, leaving a lot of surplus roots with the farmers. Fortunately, this was the same time insecurity in the region was at its peak and many people had been forced to live in protected camps. Displaced people had fled rebel insurgency in the various districts that included Lira itself, Apac and especially Pader district. Pader is

Table 2: Scale-up distribution of planting material in war affected areas of the Northern Uganda 2002/2003.

District	No. of bags	Estimates vine cuttings	Estimated area (ha)
Soroti	640	1,536,000	51.2
Gulu	150	360,000	12.0
Pader	50	120,000	4.0
Apac	620	1,488,000	49.6
Lira	434	1,041,600	34.7
Totals	1894	4,545,600	151.5

Table 3: Some of the farmer groups that have benefitted from the expanded distribution of planting materials received from Jamee Arwata Foundation (2002/ 2003).

District	Sub-county	Groups
Lira	Ogur Dokolo Kwera	Akakan, Agweng, Alyec Youth Amwoma, Iguli, Akolodong Apennyang, Agen farmers
Gulu	Bobo	Patek Youth, Adak Women group
Apac	Acaba Inomo Aduku Chegere Minakulu Bala	Ocolo, Apurubonyo, Acaba Youth tree planting group Ajok 'A', Ajok 'B' Ikweru, Adyeda women group Apoki Women Guild Assoc. Omoladyang, Abongwen Youth Afforestation
Soroti	Gweri	NAADS groupsSOCADIDO groups
Totals		>19 groups

one of the rebel hot spots and is neighbouring Lira district. JAF, in its noble mission of joining hands with policy makers, NGO's, research organizations and the rural poor, to bring hope to the hopeless, using funds provided by PRAPACE, donated an estimated 7 tones of orange-fleshed sweetpotato roots to displaced persons in Lira municipality in Lira district. It is estimated that at least 8021 displaced persons (about 1367 households) were fed by the donated sweetpotato. JAF linked to more other organization for a hand in achieving this noble cause. For example, the Lira district administration provided a vehicle that helped to transport sweetpotato fresh roots from three different sub-counties to the distribution centers. Uganda Red Cross volunteers handled the distribution to the affected people. The distribution exercised was overseen by the district administration, UNICEF. The media also witnessed the distribution of the sweetpotato and later helped to publicize the activities by JAF and indeed the orange-fleshed sweetpotato.

This supplemented the traditional cereals and beans that continued to be given out by World Food Program, and the artificial vitamin A tablets given by UNICEF.

The first distribution created demand from other organizations to extend the supplies to other camps in more affected areas of Gulu. In 2003, JAF in collaboration with World Vision International distributed about thirty tones of fresh roots to displaced peoples camps in Gulu.

Achievements

JAF's activities to disseminate orange-fleshed sweetpotato in the war-torn areas of northern Uganda present a number of achievements to JAF and its partners.

Expanded multiplication of orange-fleshed sweetpotato has increased food availability in households and yielded surpluses that have fed displaced people in the various camps (including disparate babies and women). Since its inception, JAF estimates to have distributed planting materials to over 120

groups (included women and youth groups) to all the war affected districts in Northern Uganda. Some of the groups are displaced people who carried planting material back to their villages as conditions improved. On the food relief side, JAF estimates to have distributed over 60 tones of orange-fleshed sweetpotato that is estimated to have fed over 300,000 affected persons (53,000 households) living in the camps in both Lira and Gulu districts for approximately two days each household (Red Cross Relief staff- personal communication)

Financial benefits have also accrued to farmers' and women's groups through the sales of vines and sweetpotato roots. In a period of about a year, participating farmers earned over US\$ 12,000 from sales of vines alone. These earnings are seen as incentives to farmers to sustain production and wider dissemination of orange fleshed sweetpotato in the north especially as the security situation improves. These farmers have become keener and for the first time in the region vines were maintained through the dry season.

These activities have thus contributed in restoring hope among the people. This is reflected in ambitions of Mr. Albino Ebwol, chairperson of Alidi farmers group, when he was asked by Uganda television of what he expected to gain with the sweetpotatoes. He hoped to buy a car and his fellow farmers would build decent permanent home buildings.

JAF has successfully involved and captured the interest of local opinion leaders into its activities on orange-fleshed sweetpotato. A number of officials from the district local councils have also become growers of OFSP.

JAF as an organization has won recognition and appreciation from the local leadership, which is critical for its future activities. For example a vote of appreciation to JAF was discussed and passed by the district council. The council is the local legislating and planning unit at the district. The appreciation recognized the uniqueness of the donated sweetpotato varieties that are

rich in vitamin A and would therefore fight malnutrition in addition to food security.

Lastly promotion of orange fleshed sweetpotato has presented JAF with valuable knowledge and experience in dealing with desperate people that live under continuous uncertainty.

Challenges

Future strategy. It is hoped that the security situation in some parts of the region will improve while other parts remain insecure. JAF will continue to work with farmers in the camps in areas whose security situation is envisaged to improve by availing clean planting material and establish multiplication gardens for the vines. These will be sources of more vines as people settle back into their homes. The multiplication will also be done with people in camps in areas still prone to insecurity to encourage them produce supplementary food using areas within the surroundings of the camps. This will also serve to conserve the vines for these affected families hoping for improvement in the security situations in their areas. Farmers in all the cases will be trained on good cultural practices of producing sweetpotatoes as well as post harvest handling aspects in events of over production. JAF also hopes to continue working with its partners to provide sweetpotato to displaced persons by buying of the surplus from the farmers in secure areas. It will also seek to widen the partnership to more organizations with the aim of getting further support to widen impact to reach all the affected people in the North.

Acknowledgements

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Farmers' perception and varieties acceptability of orange-fleshed sweetpotato in Zanzibar

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Abstract. Ten orange fleshed sweetpotato varieties were introduced in Zanzibar from CIP-Nairobi in November, 2001. The materials received in the form of mini-cuttings were initially maintained and evaluated and bulked at two research stations, Kizimbani and Matangatuani before being sent for on-farm trials. Five elite clones were participatorily selected and taken on-farm for further evaluation and selection. On-farm, (at farmer Field Schools and Farmer Research Groups) the clones were evaluated using a RCB design with each group of farmers as a replicate. Three of the clones (TIB-4, Zapallo and W-151) were highly ranked and selected by farmers and are being recommended for promotion. This paper illustrates farmers perception and the acceptability of these varieties based on their knowledge, agronomic performance and cooking qualities.

Introduction

Sweetpotato has a very important role as a food crop in Zanzibar. It has of late assumed a cash crop status in some areas of the Islands. Though it is ranked fourth after rice, cassava and banana, sweetpotato has a special role as a food security crop. During drought periods, many low income families substitute it for bread and it also features prominently in the food recipes for breaking the fast (futari) during the holly month of Ramadan.

Sweetpotato like other root and tuber crops is a heavy feeder. It does not do well in marginal land therefore farmers in some sweetpotato producing areas of Zanzibar like

Donge Muwanda use urea to improve the fertility of the soil for good production of the crop. Generally, the yield of sweetpotato in Zanzibar is low. Previous studies (COSCA, 1995; KAP Survey, 1994) reported that the average yield of sweetpotato was as low as 5 – 8 t/ha. However, the recently conducted baseline study of cassava and sweetpotato in Zanzibar (Nov, 2001) has revealed that average yield of some selected varieties were as high as 13-15t/ha in farmers' fields (Saleh *et al.*, 2001). Among the important constraints reported to cause the low yield of sweetpotato in Zanzibar were lack of capital for sweetpotato production, poor soils because of continuous cropping on the same piece of land, the use of poor quality vines and growing genetically low producing and disease and pest susceptible varieties (Op cit, 2001). Therefore, there is a need to look for new improved varieties that will be acceptable to farmers. The locally improved varieties SPN/O was introduced in the Islands by the Department of Research in the last few years and it is still the most important variety in the Islands, grown by more than 39% of the farmers (Op cit, 2001).

Sweetpotato in Zanzibar is grown both in the plantation zones where soils are rich and moisture is adequate and at the semi coral rag zone e.g. Bambi juu, Upenja etc. where soils are poor and moisture stress is a common phenomenon. Therefore the availability of drought tolerant varieties in these areas is very important. An experiment was therefore conducted to evaluate, with farmers' participation, the performance of introduced

varieties, and select those that meet farmers' growing conditions and eating qualities.

Materials and Methods

The experiment was conducted in 8 sites for two seasons (2001/2002 and 2002/2003) using seven varieties. Five of them (TIB-4, Salyboro, Zapallo, Tainung 65 and W-151) were introductions from CIP, two were local (SPN/O and Shangazi). All the five CIP varieties are orange-fleshed. They were selected by farmers from among 10 introductions planted on-station. The randomised complete block design (RCBD) was adopted with each site treated as a replication. Each variety was planted on three ridges 10m long and 1m apart. Within rows plants were spaced 0.3m from each other. No fertilizers or herbicides were applied on the plots to simulate farmers' conditions as much as possible. Four farmer field schools (FFS), two Farmer Research Groups (FRG) one prison camp (Magereza) and an individual farmer were involved in the experiment where farmers participated in all activities, from site selection to evaluation of the trial.

The vines were sourced from healthy and young mother stocks. Shoot tip cuttings 25 – 30 cm long were used. At each site soil samples were taken before planting for laboratory analysis. The following data were also taken: plant establishment (%), root yield (kg/plot), number of roots per plot, number of marketable roots per plot, number of non-marketable roots per plot, weight of marketable roots (kg/plot), weight of non-marketable root (kg/plot) and dry matter content (%).

Data were statistically analysed using M stat c computer software. Farmers assessed the varieties in the field using a scale of 1-5 (where 1 = very poor and 5 = very good) for the following characteristics: resistance to diseases, resistance to pests, drought tolerance, maturity, root shape, root size, general root appearance and flesh colour of roots.

The roots were then boiled and farmers assessed each variety for the following characteristics using a scale of 1-3 (where 1 = very good and 3 very poor): Appearance, taste, flavour, starchiness, fibrousness and general acceptability. Data were statistically analysed using the SPSS statistical software.

During the assessment, the varieties were given numbers instead of their actual names to reduce biasness in ranking of popular varieties. For each attribute the majority score was taken for each variety.

Results and Discussion

Soil nutrient content. The results of soil sample analysis are presented in Table 1. In general the soil sample analysis shows that soil fertility status in experimental sites was not a factor that could influence the performance of the sweetpotato varieties.

The Upenja site lies within the semi-coral rag zone (with soils mixed with coral stones). The Fujoni FFS site is situated in the rice valleys of the sandy belt of northern part of Unguja Island. The rest of the zones lie between the belts of plantation area and multi-storey crop patterns.

Farmers' field assessment. The average performance (mean score for all characteristics) of each variety across sites and the overall rank for each is presented in Table 2. In general, SPN/O was the high ranked variety, followed by the orange-fleshed varieties W-151 and Zapallo. Salyboro was the least preferred variety. The local control (Shangazi) was ranked second last (Table 2). This result proves that farmers can evaluate and select their preferred varieties according to their own criteria, skills and experiences.

The mean performance of the varieties for different agronomic traits across 8 sites is presented in Table 3. Significant differences ($P = 0.05$) were observed between varieties for percentage establishment (Table3). Varieties SPN/O and Zapallo had highest percentage establishment of 97.75% and

97.38% respectively, where as variety Salyboro had the lowest (80.94%).

Varieties differed significantly in the number of marketable roots/plot (Table3). SPN/O had the highest number (23) whereas Salyboro and Tainung 65 had the lowest (12). No significant differences were detected between varieties for marketable root weight with a range of 3 – 7 kg/plot (Table3). All the varieties had dry matter contents above 30%.

However, varieties Shangazi (local check), SPN/O, Salyboro and TIB –4 had the highest dry matter contents. The differences between varieties were statistically significant (Table 3).

The mean site performance for the various agronomic characteristic is presented in Table 4. Significant differences existed between sites for number of marketable and non-marketable roots, and dry matter content. No significant

Table 1: Soil properties across eight experiments sites.

Site	Soil type	Sample depth (cm)	pH H ₂ O 1:2.5	Total N ¹ . %	P ² ppm	K ³ meq K ₂ O/100g soil	Na ³ meq/ 100g soil
Mitakawani	Sandy clay loamy	0.30	6.1	0.145	4	0.041	0.111
Junguni	Silt loamy	0.30	7.2	0.100	23*	0.060	0.135
Fujoni	Sandy clay	0.30	6.4	0.084	3	0.064	0.489*
Kinumoshi	Clay loamy	0.30	5.7	0.334*	4	0.136	0.156
Kizimbani	Sandy loamy	0.30	5.6	0.145	6	0.248**	0.052
Upinja	Silt loamy	0.30	7.7	0.282*	45**	0.117	0.058
Matangatuani	Clay loamy	0.30	5.3	0.084	45**	0.120	0.100
Kiuyu	Sandy clay	0.30	6.4	0.066	27*	0.180*	0.207

¹Total nitrogen (N %) was determined by semi micro-Kjeldah method using block digester.

²Available P (P₂O₅) by Spectrometer from Bray and Kurtz 1 extraction.

³Available potassium (K₂O) and Extractable Sodium (Na) were analysed by absorption spectrophotometer (AAS) using NH₄Oac.

Table 2: Average performance of sweetpotato varieties for all characteristics evaluated in the farmers.

Variety	Sites								Mean	Rank
	Mitakawani	Junguni	Fujoni	Prison camp Kinumoshi	Kizimbani	Upinja	Matangatuani	Kiuyu		
TIB-4	3.73	3.34	3.64	3.30	3.09	3.45	3.36	3.54	3.43	4
Salyboro	3.18	2.90	3.18	2.50	2.90	3.09	2.55	3.00	2.91	7
Zapallo	3.73	3.55	3.81	3.36	3.27	3.36	3.63	3.72	3.55	3
Tainung 65	2.54	3.27	3.45	2.63	2.81	3.45	3.36	3.37	3.11	5
W – 151	3.90	3.82	3.63	3.27	3.63	3.73	3.81	3.72	3.69	2
SPN/O	4.00	3.72	3.81	4.00	3.73	4.00	3.81	3.73	3.85	1
Shangazi (control)	2.7	3.18	3.09	3.00	3.18	3.00	3.27	3.27	2.96	6

Field across eight sites.

N.B. Subjective ranking is 1 – 5.

Where 1 = very bad; 2 = bad; 3 = moderate; 4 = good; 5 = very good.

differences were detected between sites for marketable root weight.

Plant establishment was lowest at Upenja FRG (85%). This was not surprising because this site is dominated by poor soils (coral rag) and moisture stress is a common phenomenon. At this site, farmers rated variety Zapallo the best. Zapallo also proved the best performer under water logged conditions at Donge Muwanda (this site was

later abandoned due to floods). All the other varieties perished. Furthermore, Zapallo was highly preferred by farmers because its narrow leaves resemble those of a popular local variety whose leaves are used as a vegetable (mtoriro).

The average performance of the varieties for cooking qualities across the sites is shown in Table 5. In general five varieties (TIB-4, W-151, Zapallo and SPN/O and Tainung 65) were

Table 3: Mean performance (per plot) of seven sweetpotato varieties across eight sites evaluated by two seasons (2001/02, 2002/03).

Variety /clone	Establishment (%)	Plants with storage roots	No. of marketable roots	No. of non-marketable roots	Weight of marketable roots (kg)	Weight of non-marketable roots (kg)	Dry matter content (%)
TIB – 4	89.50	8.88	15.50	8.38	4.48 (14.9)	0.62 (2.0)	34.88
Salyboro	80.94	7.88	12.38	4.63	3.33 (11.0)	0.52 (1.7)	35.51
Zapallo	97.38	8.63	13.75	3.87	4.32 (14.4)	0.35 (1.2)	30.13
Tainung 65	75.88	7.25	12.50	6.63	7.08 (23.5)	0.46 (1.5)	30.14
W.151	92.05	8.38	16.13	6.25	4.65 (15.5)	0.61 (2.0)	31.14
SPN/O	97.75	8.70	23.38	8.75	6.72 (22.3)	0.85 (2.8)	36.16
Shangazi	92.75	8.47	22.00	5.57	5.52 (18.3)	0.55 (1.85)	36.51
Mean	89.40	8.30	16.52	6.29	5.16	0.56	33.49
LSD (0.05)	10.39	1.21	3.21	NS	NS	NS	4.88
CV (%)	8.88	14.45	42.63	69.42	96.93	77.7	11.14

Figures in brackets represent ton/ha, NS = Not statistically significant.

Table 4: Mean site performance for several agronomic characteristics of seven sweetpotato varieties evaluated for two seasons (2001/02, 2002/03).

Sites	Establishment (%)	No. of plant with storage roots /plot	No. of marketable roots/plot	No. of non-marketable roots	Weight of marketable roots (kg/ plot) roots/ plot	Weight of non-marketable roots (kg/ plot) roots (kg/ plot)	Dry matter content (%)
Mitaka. FFS	86.93	7.00	13.14	4.71	3.06	0.50	36.99
Upinja FRG	84.94	9.14	10.71	5.29	3.80	0.30	31.11
Kiuyu FRG	96.14	8.86	16.43	4.57	8.62	0.14	31.90
Fujoni FFS	91.71	9.14	15.00	5.85	5.30	0.95	33.97
Kizimbani	90.29	6.71	16.43	10.29	4.44	0.76	29.67
Kinumoshi	92.58	9.57	17.00	9.00	5.23	1.06	33.57
Junguni FFS	86.29	8.86	18.50	5.28	3.97	0.35	31.66
Matangatuani	86.82	8.43	24.80	5.57	6.78	0.24	34.09
Mean	89.46	8.46	16.50	6.32	5.15	0.53	32.57
LSD (0.05)	9.38	1.45	8.33	5.04	NS	0.52	4.412

Table 5: Mean scores of seven sweetpotato varieties for seven cooking characteristics evaluated across eight sites for two seasons (2001/02, 2002/03).

Site	Average score (1-3) for combined attributes per variety.						
	Varieties						
	TIB-4	Salyboro	Zapallo	Tainung	W-151	SPN/O	Shangazi
Mitakawani	1.00	1.50	1.17	1.50	1.00	1.70	2.00
Upinja	1.00	1.50	1.33	1.17	1.17	1.33	1.33
Kiuyu	1.00	2.00	1.50	1.00	1.00	1.67	2.16
Fujoni	1.67	1.50	1.33	1.67	1.60	1.00	1.67
Kizimbani	1.00	1.66	1.67	1.33	1.17	1.33	1.50
Kinumoshi	1.17	1.67	1.00	1.67	1.17	1.00	1.67
Junguni	1.00	1.83	1.00	1.50	1.00	1.17	1.83
Mat/tuani	1.17	1.67	1.17	1.33	1.00	1.17	1.33
Overall mean	1.12	1.66	1.27	1.39	1.13	1.29	1.68
Overall rank	1	6	3	5	2	4	7

N.B The subjective ranking score is 1-3 where as 1 =good, 2 moderate and 3 = bad.

Table 6: Mean scores of six sweetpotato cooking characteristics for seven varieties evaluated across eight sites for two seasons (2000/01, 2001/02).

Sites	Attribute (Score 1-3)							Rank
	Appearance	Taste	Flavour	Starch	Fibrousness	General acceptability	Mean	
Mitakawani	1.57	1.14	1.42	1.42	1.14	1.28	1.33	5
Upinja FFS	1.28	1.00	1.57	1.51	1.00	1.14	1.26	1
Kiuyu	1.57	1.42	1.42	1.28	1.14	1.57	1.40	8
Fujoni FFS	1.42	1.28	1.14	1.42	1.14	1.28	1.28	3
Kizimbani	1.20	1.28	1.42	1.42	1.00	1.28	1.30	4
Kinumoshi	1.42	1.00	1.57	1.57	1.14	1.42	1.33	5
Junguni	1.57	1.42	1.28	1.28	1.14	1.28	1.33	5
Mat/tuani	1.28	1.28	1.42	1.42	1.00	1.42	1.26	1
Mean	1.44	1.22	1.38	1.45	1.08	1.33		
Rank	5	2	4	6	1	3		

Ranking score 1-3 (1=good, 2=moderate, 3= bad).

rated “good” across the sites. Two of them (Salyboro and the local check-Shangazi) were rated “moderate” (Table 5).

All the cooking qualities were rated good for all the varieties across sites. It is also noteworthy that these varieties were not fibrous and tasted sweet (Table 6). Farmers in

Zanzibar prefer non-fibrous sweet varieties (Saleh and Mohammed, 2001).

Conclusion and Recommendations

From this experiment, it was observed that farmers’ participation in selection of the

varieties is very important in enhancing adoption of new technologies (varieties). Farmers Field School and Farmers Groups were vital in this work.

All the seven varieties possessed had attributes desirable to farmers. All the seven varieties will therefore be recommended to farmers. Farmers at each agro-ecology will select the varieties to adopt.

More on-farm testing of these varieties should be encouraged. In addition, measures should be put in place for multiplying and distributing quality planting materials for the selected materials.

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Acceptability studies of orange-fleshed sweetpotato varieties in Uganda

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Abstract. Use of orange-fleshed sweetpotatoes (OFSP) as a food-based approach has been suggested as an alternative option to combat vitamin A deficiency (VAD) in Uganda. The OFSP have high β -carotene and are seen as a cheaper and complementary source of vitamin A for the rural poor families who are the most vulnerable to VAD in Uganda. The opportunity is that about 90% of the rural poor households in Uganda use sweetpotato as a staple or co-staple. However OFSP are not known to most of the communities. In this study, we used farmer managed trials as a way of screening and introducing OFSP varieties to communities in Uganda. The study has shown that Ejumula and SPK 004 are the most accepted OFSP varieties in Uganda. Good yields and appealing flesh colour were the reasons put forward for their acceptance by both adults and children.

Introduction

In Uganda about 28% of children and 60% women are reported to be vitamin A deficient (VAD) (UDHS, 2002). The deficiency exposes children to common illnesses, impairs their growth, development, vision as well as immune systems. In severe cases it results in blindness and death (Ruel, 2001), with between 15000 and 60000 death cases reported annually. In women, VAD increases the risk of death during pregnancy, results in low birth weight in children and may increase

chances of HIV/AIDS infection. In Uganda campaigns to combat VAD include among others administration of vitamin A capsules and vitamin A rich natural and fortified foods. Although these have a positive impact, their sustainability is poor especially for the rural poor. Food-based approaches are seen as a viable option for the rural poor. In Uganda, vitamin A rich crops that can be adopted by the rural populations include carrots, fruits and green vegetables. The potential is even bigger with the orange fleshed vitamin A rich sweetpotatoes. Unlike other crops, sweetpotatoes grow and are consumed almost across the country. About 90% of the rural poor households eat sweetpotato as a staple or co-staple, leading to a per capita consumption of 119 kgs. Unfortunately, the cultivation of OFSP has not been widely adopted. Studies were therefore conducted to introduce and evaluate the acceptability of the OFSP varieties among the rural poor communities in Uganda.

Materials and Methods

Seven sweetpotato varieties, namely Ejumula, SPK 004, Kala, Sowola 6, Sudan, 4-4, and Naspot 5 were evaluated between 2001 and 2003 in seven districts representing three major agro ecological zones (Tables 1 and 2). SPK 004 is an introduction from Kenya while the rest are local Ugandan varieties. The seven districts were Kabale, Ntungamo, Mpigi, Luwero, Busia and Soroti. Of the seven

Table 1: Morphological characteristics of orange-fleshed sweetpotato varieties tested in different agro-ecologies of Uganda.

Variety	Flesh colour	Skin colour	Maturity	DM category
Ejumula	Deep orange	Cream	4	High
SPK 004	Orange	Red	4	High
Kala	Light Orange	Cream	4	High
Sowola 6	Orange	Cream	5	High
Sudan	Orange	Cream	6-7	High
4-4	Light Orange	Cream	5	High
Nasplot 5	Light Orange	Red	5	High

Table 2: Characteristics of different agro-ecologies of sweetpotato in Uganda.

Region	Locations	Rainfall (mm)	Topography	Vegetation
Central	Mpigi Luwero	1200 - 1500	Low land	Tropical rain forest
Eastern	Busia Soroti	500 - 1200	Low land	Dry savanna grassland
South Western	Ntungamo Kabale	1500 - 1750	Highlands	Montane grass land

varieties only Ejumula, SPK 004 and Kala were evaluated in all the sites. The evaluation was done with farmer research groups. Access to these groups was made through grass root organizations - AFRICARE in Kabale, VEDCO in Luwero, and SOCADIDO in Soroti. Individual volunteer farmers adopted a mother baby trial system where each group established a group trial and other trials. The trials were planted and managed by farmers. They also made observations throughout the trials' life cycle and also collected data. The plot sizes and methods of planting varied with locations. Five months after planting, the trials were harvested and evaluated for performance. Various attributes were assessed using a subjective score of 1-5, where 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good. Field performance attributes used for varietal assessment were foliage coverage, resistance to diseases and pests, drought tolerance, maturity period, root yield, shape and size of roots, root skin

appearance, root flesh appearance and general crop appreciation. Crop yield was also recorded. In addition, sample roots of each of the harvested varieties were peeled, cooked and served separately to children between 7 and 10 years and adult men and women. Cooked roots were assessed for appearance, taste, flavour, starchiness, fibrousnesses and general acceptability using a similar subjective scoring used in the field. Pair wise rankings of varieties were also done for both field performance and consumer acceptance (Chirimi *et al.*, 2000; Munga *et al.*, 2000, Wanjekeche *et al.*, 2000). Data analysis was carried out using the Statistical Package for Social Sciences (SPSS).

Results and Discussions

Yields of orange-fleshed sweetpotato varieties in Uganda. Sweetpotato storage root yields across sites are presented in Table 3. The yields varied with varieties and across

Table 3: Indicative yield* performance of OFSP varieties in different agro ecologies of Uganda between 2001 and 2003.

Location	Root yields (t/ha) of orange-fleshed sweetpotato varieties						
	Ejumula	SPK 004	Kala	Sowola 6	Sudan	4-4	Nasplot 5
Luwero	5.2	3.9	5.0	-	-	-	-
Mpigi	10.0	7.3	10.6	4.4	-	7.1	2.5
Kabale	12.7	8.0	9.6	7.3	-	11.0	1.7
Busia	9.5	8.3	12.3	5.3	6.7	7.5	-
Soroti	8.9	8.0	8.7	5.2	6.7	1.2	-
Ntungamo	25.1	12.5	10.3	9.8	16.3	-	-
Mean	12.1	8.0	9.4	6.4	9.9	6.6	2.1

*Yields are averaged over years.

locations. Overall variety means across locations showed that Ejumula was the highest yielding variety (12.1 t/ha). Apart from Mpigi and Busia, Ejumula yielded higher than the other varieties in the rest of the locations. This suggests that it may be a yield stable variety. This was followed by Sudan, Kala, and SPK 004. Although Nasplot 5 yield estimates are not across all study sites, it gave the least average yields (2.1 t/ha), confirming reports from farmers and field extension officers about the poor yields of this variety.

A comparison of on-farm and on-station yields for the 3 best yielding varieties (Table 4) reveals great yielding potential of these varieties under improved agronomic practices. For example Ejumula can yielded up to 38 t/ha, which is well beyond the national average (Mubiru, 2000). The observed yield variation is probably due differences in the yielding potentials of the different varieties and

differences in the climatic conditions across the locations (Mubiru, 2000).

Field evaluations of OFSP varieties by farmers. Evaluation data for OFSP varieties is presented for 2 districts, Luweero and Soroti. In Luwero, farmers ranked Ejumula the best variety at field level (Table 5). Detailed data presented in the table seem to suggest that farmers liked Ejumula for its flesh root appearance, yield, as well as good root characteristics like shape and size. However, it is important to note farmers' dissatisfaction with Ejumula over its poor foliage coverage, disease and drought tolerance. Ejumula is known to be susceptible to virus infections (Mwanga *et al.*, 2004). This together with poor tolerance to drought affects the foliage cover of the variety, which in turn affects planting material availability at the on-set of the season. Good seed multiplication schemes that aim at maintaining clean planting material are recommended as a solution if Ejumula is to be widely adopted by farmers in Uganda. Field assessment results from Soroti (Table 6) were similar to Luweero results. Similarly, results obtained from the rest of the districts revealed a similar trend.

SPK 004 was ranked the second in Luwero despite its low scores on general variety appreciation than Kala and the local checks. This is probably due to better foliage coverage, pest and disease resistance and

Table 4: On farm and on station yield performance comparison in Uganda.

Variety	Yield (t/ha) ranges	
	Farmers' fields	On-station
Ejumula	5-17	12-38
SPK 004	5-16	14-35
Kala	3-13	10-33

Table 5: Farmers assessing* orange-fleshed sweetpotato varieties in Luwero district, Uganda 2001/2002.

Variety	Foliage cover	Disease resistance	Pest resistance	Drought tolerance	Early maturity	Root yields	Root shape	Root size	Skin appearance	Flesh appearance	General acceptance	Rank
Ejumula	2.5	2.7	3.2	2.7	3.8	3.8	3.9	3.7	3.7	4.1	4.2	1
SPK 004	3.6	3.9	4.0	3.7	3.3	2.9	3.1	2.9	3.5	3.5	3.5	2
Kala	3.1	3.5	3.7	3.3	3.5	3.6	3.6	3.3	3.4	3.2	3.8	3
Local checks	3.9	4.0	4.1	3.9	3.5	3.5	3.6	3.4	3.7	3.6	3.9	5
Mean	3.3	3.5	3.8	3.4	3.4	3.5	3.6	3.3	3.6	3.6	3.9	-
CV %	18.6	16.9	10.8	15.6	5.8	11.2	9.3	10.0	4.2	10.4	7.5	-

*Subjective ranking: 1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good; N = 103.

Table 6: Field assessment* of orange-fleshed sweetpotato by farmers in Soroti district, Uganda 2002/2003.

Variety	Foliage cover	Disease resistance	Pest resistance	Drought tolerance	Early maturity	Root yields	Root shape	Root size	Skin appearance	Flesh appearance	General acceptance	Rank
Ejumula	3.6	3.8	3.6	4.0	4.2	4.4	4.3	4.3	4.3	4.5	4.5	1
SPK 004	4.3	4.9	4.0	4.1	3.7	3.8	3.8	4.1	3.8	3.9	4.0	2
Kala	3.3	3.7	4.0	3.9	4.1	4.1	4.1	3.9	4.1	4.1	4.1	3
Sowola 6	3.9	4.0	3.9	4.0	3.4	3.1	3.2	3.2	3.6	3.7	3.5	5
Sudan	3.8	3.9	3.7	4.0	3.6	3.7	3.2	3.3	3.6	3.7	3.9	4
4-4	3.6	3.9	4.2	3.3	2.3	2.0	2.1	2.1	2.0	2.7	2.2	6
Mean	3.8	4.0	3.9	3.9	3.6	3.5	3.5	3.5	3.6	3.8	3.7	-
CV %	9.0	10.9	5.6	7.5	19.2	24.6	22.9	23.0	22.6	15.8	21.7	-

* 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good; N = 112.

flesh root appearance. During assessments farmers asserted that SPK 004 had more and clean planting material and envisaged no planting material scarcity for the variety compared to Ejumula. Farmers in Soroti, like in Luwero were dissatisfied with Ejumula's foliage coverage, disease and pest resistance. However, unlike in Luwero farmers in Soroti found Ejumula tolerant to prolonged dry weather. This is probably due to the fact that the variety originates from this area and is probably adapted to the local conditions (Mwanga *et al.*, 2004). Similarly, SPK 004 was the second best preferred variety in Soroti. Apart from dissatisfaction with yields, farmers seem to like it for its good foliage coverage, root shape and size. The variety, 4-4 performed poorest and was the least preferred in Soroti for field performance. This was primarily because of its poor yields, which was associated with small and poor shaped roots. The variety was also late maturing.

Although the local varieties were generally the least preferred, they were scored above moderate for foliage coverage, pest and disease resistance as well as tolerance to prolonged dry spells. Local check varieties consisted of varieties that have over a period been grown by farmers and were already liked for a number of attributes including adaptability.

Consumer acceptability studies of orange-fleshed sweetpotato. Unlike for field assessment of the OFSP varieties where only adults were involved, both adults and children participated in consumer acceptability tests of the varieties. Results from two study sites, Luwero (Table 7) and Soroti (Table 8) are presented.

In Luwero, both adults and children generally preferred the cooked roots of Ejumula to the rest of the varieties. Whereas adults felt that Ejumula is good for all the

Table 7: Assessment* of cooked OFSP in Luwero district, Uganda, during 2001/2002.

Varieties	Consumer acceptability attributes assessed by farmers						Over all Rank
	Appearance	Taste	Flavor	Starchiness	Fibrousness	General acceptance	
Adults (N = 119)							
Ejumula	4.5	4.2	3.9	4.1	4.1	4.4	1
SPK 004	3.8	3.8	3.7	3.8	3.7	4.2	2
Kala	3.4	3.7	3.3	3.9	3.3	4.0	4
Local checks	3.1	3.5	3.4	3.8	3.5	3.9	3
Means	3.7	3.8	3.6	3.9	3.7	4.1	-
CV	16.4	7.7	7.6	3.6	9.2	5.4	-
Children (N = 105)							
Ejumula	5.0	4.8	4.7	4.8	4.2	4.8	1
SPK 004	4.2	4.2	4.0	4.6	3.3	4.2	2
Kala	4.0	3.9	3.7	4.7	3.4	3.9	3
Local checks	3.9	4.1	3.6	4.6	3.5	3.8	4
Means	4.3	4.3	4.0	4.7	3.6	4.2	-
CV	11.6	9.0	12.4	2.0	11.3	11.8	-

*1 = very bad, 2 = bad, 3 = moderate, 4 = good, 5 = very good.

Table 8: Post harvest assessment of orange-fleshed sweetpotato by adults and children in Soroti, Uganda 2002/2003.

Varieties	Consumer acceptability attributes assessed by farmers						Over all Rank
	Appearance	Taste	Flavor	Starchiness	Fibrousness	General acceptance	
Adults (N = 115)							
Ejumula	4.5	4.4	4.1	3.7	3.9	4.3	1
SPK 004	4.0	4.3	3.9	3.9	4.1	4.3	2
Kala	4.1	4.0	3.9	3.9	4.0	4.2	4
Sowola 6	3.8	3.9	3.6	3.6	4.0	3.8	5
Sudan	4.2	4.4	4.2	4.1	4.0	4.3	3
4-4	3.3	3.5	3.4	3.5	3.4	2.8	6
Means	4.0	4.1	3.9	3.8	3.9	4.0	-
CV %	10.2	8.6	7.7	5.9	6.4	15.1	-
Children (N = 49)							
Ejumula	4.5	4.1	3.9	4.0	4.3	4.3	1
SPK 004	3.8	3.9	4.0	4.0	4.2	3.7	4
Kala	4.1	4.1	4.4	4.4	4.3	3.9	2
Sowola 6	3.7	4.3	4.1	3.8	4.2	3.8	5
Sudan	3.8	4.1	3.9	3.9	4.1	4.0	3
4-4	3.4	3.1	2.9	2.9	3.3	2.9	6
Means	3.9	3.9	3.9	3.8	4.1	3.8	-
CV %	9.7	11.0	13.0	13.2	9.3	12.4	-

Subjective ranking: 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good.

attributes except flavour, children felt it was good in all attributes. Children were emphatic on the cooked root appearance, which they all felt was very good for them. The dissatisfaction expressed by adults on the flavour of Ejumula, is probably due to the squash-like-flavour characteristic of most OFSP varieties. For adults, SPK 004 cooked roots were the second most preferred variety, followed by Kala and lastly the local checks. In Soroti, Ejumula was the best variety for both adults and children. However, the two age groups differed on the second preferred variety. While adults chose SPK 004 as the second best variety, children preferred Kala.

Farmers' observations on the overall acceptability of orange-fleshed sweetpotato. This section presents sentimental comments

made by farmers at different times during the evaluation process of the OFSP varieties. In Soroti for example, a farmer observed, "It is very sweet and we do not even need sugar while taking our tea". Sweetpotato is commonly used for breakfast in many Ugandan households. In Kabale, a male farmer referred to the appearance of the varieties as that of "egg yolk". There is a general perception that eggs are a nutritious food among Ugandan communities and therefore this resemblance implies that OFSP are nutritious. In Mpigi, a farmer likened the appearance of cooked roots of OFSP as of cooked bananas. In Central Uganda people have a historical liking for bananas and therefore any association of the OFSP with bananas suggests acceptance among the people in this region. A lot more testimonies

have been heard from mothers. “My children enjoy eating orange types of sweetpotato” many mothers were heard commenting during the evaluations.

Conclusions

It is clearly evident from the findings of the study that OFSP varieties are acceptable to the rural based communities in Uganda. Ejumula and SPK 004 are the most accepted varieties in Uganda for both field and consumer performance. At field level they produced average good yields and were also liked for their starchiness by adults and appearance, largely by children. However, Ejumula the best variety suffers from viral infections and is affected by prolonged drought, resulting in scarcity of planting material at the on-set of rains. These studies have introduced more adapted, high yielding, disease resistant and equally acceptable OFSP varieties.

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Implication of variation in aggressiveness of *Phytophthora infestans* (Mont.) de Bary isolates found in Kenya to potato production

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Abstract. A survey was carried out to determine the incidence and severity of late blight in four major growing potato districts. *Phytophthora infestans* isolates were found to have varying levels of aggressiveness as indicated by their reaction on tubers and detached leaves. The variability of ten different isolates of *P. infestans* was evaluated by their ability to cause disease on both detached leaf and tubers of different potato genotypes. Isolate 023 had the largest lesion diameter of 35.67mm on leaves of Kerr's Pink variety and this was significantly ($P < 0.05$) higher than all the other lesion diameters recorded on other isolates. Isolate 032, with a lesion diameter of 13.33mm, was the only isolate regarded as virulent on the leaves of variety Kenya Sifa. There were no isolates regarded as virulent on variety Kenya Rutuku.

On tuber rot, isolate 008 was the most virulent with a diameter of 16.04mm. Isolate 035 was considered least virulent with a mean diameter of 10.04mm. Isolate 008 was the most virulent isolate with a diameter of 16.04mm.

Cultivation of some popular varieties like Kerr's Pink has become impossible, as the variety is highly susceptible to the disease due to the emergence of more aggressive strains. These developments also imply that the late blight management has to be broadened to include tubers reactions to *P. infestans* in order to avail farmers varieties that meet their requirements.

Requirements and characteristics of potato varieties in the Kenyan potato processing agricultural sub-sector

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Abstract. Crop utilization is an important facet of potato production. Processing potatoes adds value and diversify ways in which they are consumed. In Kenya, the increasing demand for processing potatoes has been spurred among other things by increased tourism, urbanization and changing food habits as well as increased wealth culminating into an expanding processing subsector whose integration in the food production chain is crucial for Kenya's agro-industrial development and long term food security. The objective of the study was to determine the potato quality requirements by processors, and to assess potato processing potential of several varieties and clones obtained from various sites in the country. An informal survey of the potato processing industry in Nairobi was conducted, followed by quality evaluation of potatoes grown in different sites

in the country. The potato tubers were evaluated for dry matter content, then processed into chips and crisps and subjected to sensory evaluation using an untrained sensory panel. The commonest potato products on the market were found to be chips (French fries) and crisps. Two varieties, namely, Nyayo and Roslin Tana were commercially most often used in processing into chips while Kerr's Pink and Dutch Robjin were commonly used for crisp production. Newer varieties like Tigoni and Asante were slowly gaining roots in commercial production, as the National Potato Research Centre, Tigoni, develops other varieties. Varieties with high dry matter content were found to be more acceptable when prepared into chips and crisps, than those with low dry matter content.

Participatory approach in the development of technologies to control erosion for sustainable cassava production in Thailand

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Abstract. During the first 2-3 months of cassava canopy establishment, part of the soil remains exposed to the direct impact of rainfall, which can cause serious erosion. Complete canopy closure in a cassava crop takes a long time. If farmers do not apply fertilizer to cassava, soil fertility may decline while plant nutrients in the soil may be lost due to erosion when the crop is grown on slopes. Although nutrient extraction and removal by cassava tends to be less compared with many other crops, soil loss due to erosion may be higher because of the crop's slow initial development. Past research has shown that fertilizer application, reduced tillage, contour ridging, mulching, intercropping and the planting of contour hedgerows can greatly reduce erosion. Nevertheless, farmers seldom adopt such soil conservation practices, mainly because the recommended practices are not suitable for the local conditions. They may be too costly or require too much labor, or they may be ineffective. Moreover, farmers are often not aware of the amount of soil lost

by erosion. Results of the farmer participatory research (FPR) project in various pilot sites in Thailand indicate that farmers should make their own decisions, and that they are willing to adopt soil conservation practices such as the planting of contour hedgerows of vetiver grass or legumes, if these were shown to be effective in reducing erosion. The use of a farmer participatory approach was very effective as many farmers readily adopted the selected practices and also helped disseminate these to farmers in neighboring communities. The selected practices would be well-adapted to the local conditions if the farmers made their own decisions and were directly involved in the development of new technologies by planning and implementing the trials together. This is of fundamental importance for enhancing the sustainability of cassava production.

The effect of orange fleshed sweetpotato on vitamin A and nutritional status of pre- school children in Nambale division Busia district

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Abstract. An interventional study was carried out to determine the effectiveness of orange-fleshed sweetpotato in improving the vitamin A status of pre-school children. The study was conducted in Busia District of Western Province, Kenya. The trial lasted 60 days in a primary school that was purposively selected. The children involved were from middle and low socio-economic status, and were aged between 3 and 7yrs. All the children were treated with SP anti-malarial and de-wormed with mebendazole tablets before and towards the end of the intervention. Two intervention groups were identified among children who met the selection criteria. Baseline and final data were collected from these children and their families. Data were collected for blood haemoglobin levels, erythrocyte sedimentation rates, malaria parasites, serum retinol, serum zinc, and total carotenoids. Additional data and anthropometrical measurements were also taken.

Introduction

Vitamin A deficiency (VAD) is an important cause of blindness in children. It is known that mild or sub-clinical VAD causes impaired immune function (Semba *et al.*, 1994) and increases the risk of mortality from infectious diseases (Sommer *et al.*, 1984; Fawzi *et al.*, 1993). Many developing countries have VAD as a public health problem due to inadequate intake of vitamin A from food (Underwood, 2000). The prevalence of vitamin A alone in children under five is 84% (Mwaniki *et al.*,

1999). Food-based strategies such as food fortification, dietary diversification through home gardening and school health programmes are some of the strategies being used in Kenya. Dietary vitamin A is available as preformed vitamin A, in animal products, and provitamin A carotenoids is found in orange-colored fruits and vegetables. Orange-fleshed sweetpotato (OFSP) are known to be rich in carotenoids especially beta-carotene (Jan Low *et al.*, 1997). Work done by the International Potato Center (CIP) and Kenya Agricultural Institute (KARI) in Nyanza Western Province of Kenya indicates that feeding children daily with OFSP could ensure that the recommended daily allowance for vitamin A (RDA) is achieved. This study was therefore undertaken to ascertain the importance of using OFSP to maintain the vitamin A status of pre-school children in Nambale Division, Busia district, Kenya. The main of the study was to determine the effectiveness and contribution of the orange-fleshed sweetpotato porridge on the vitamin A status of pre-school children in Nambale Division, Busia District. Specifically, the study sought to (i) determine the socio-economic and social demographic characteristics for the selected households of pre-school children in Nambale Division Busia District; (2) determine the morbidity patterns and experience in the selected pre-school children during the intervention; (3) determine the type, frequency and quantity of intake of vitamins A rich food sources by the pre-school children; (4) carry out

proximate analysis of OFSP flour for carotenoids; (5) determine baseline and post-intervention micronutrient status (specifically serum retinol, total carotenoids, serum zinc and haemoglobin levels and malaria parasite count) of pre-school children in Nambale Division Busia district; and (6) determine the nutrition status (anthropometrical measurements) among the selected pre-school children.

Research Methodology

Study area. The study took place in Busia district (K), Nambale Division. Busia district is in Western Province of Kenya. The District borders westwards with the Republic of Uganda. Nambale has an area of 232.5 square kilometers and its permanent water source is L. Victoria and has a population of 67,544. The main economic activity is agriculture with emphasis on food crops namely; sweetpotato, maize, cassava, groundnuts, indigenous vegetables, millet, maize, simsim, bananas and beans. Some people engage in petty trade. Malaria is holoendemic in this area.

Subjects. The study targeted pre-school children in the early childhood care and development centre (ECCD) aged 3 – 7yrs. Blood samples were collected from the subjects for analysis.

Variables in the study. Children were divided into two groups of 85 each. One group was fed on OFSP and the other on white-fleshed sweetpotatoes (WFSP) based porridge. The variables analyzed at baseline and post-intervention phases included serum retinol, serum zinc, haemoglobin levels, total carotenoids, malaria parasites and erythrocyte sedimentation rates.

Beta-carotene in food and serum was quantitatively determined using High Performance Liquid Chromatography (HPLC) at 445 nanometer (nm) after a homogenization and extraction procedure. Serum retinol was

determined after deproteinization of serum with methanol and subsequent extraction using hexane. Haemoglobin levels were determined using the haemocue photometer. For malaria parasites, thick and thin blood smears were made, stained with Giemsa, fixed with methanol and parasites counted and expressed per micro-litre (μ l) of blood. Serum zinc was determined using atomic absorption spectrophotometry.

The Winthrop method was used to determine erythrocyte sedimentation rates. A haematocrit tube was filled to the 100 mark with oxalated blood and allowed to stand vertically for one hour and the sedimentation rate determined using a chart specially prepared for this purpose.

Anthropometrical measurements were taken before blood sample collection. The weights and heights of the children were taken and presented as Z-scores. Mid upper arm circumferences of the study children were also measured.

Dietary assessments. The pre-tested questionnaire was administered to the children. The questionnaire was meant to determine the unquantified food frequency, 24 hr dietary recall, socio-demographic and economic parameters. Other issues captured by the questionnaire were about health and food security.

Focus group discussions. Focus group discussions with 8-10 women were conducted to enrich the information collected through the questionnaire.

Training and sensitisation of cooks and ECCD teachers. The ECCD cooks and teachers were introduced to the study. The importance of sticking to procedures, monitoring issues, compliance by children and recording of absenteeism and morbidity were emphasised. The school had three resident monitors and two cooks. The monitors were

teachers already familiar with the children, and the cooks were the taken from those employed by the school.

Standardization of the feeding regimen. The feeding regimen was first cooked and standardized in the Kenya Medical Research Institute (KEMRI) nutrition laboratory. The feed for the experimental groups was prepared in such a way to provide 100% RDA of vitamin A (in this case 300 RE µg), the maize and soy bean flours were calculated taking into consideration the calculated amounts of ingredients for basic mixes based on the edible portions of food. In this case where the staple is maize, the feed included 20gm of maize flour per serving per child supplemented with 10 gm of soybean flour. The amount of OFSP and traditional white-fleshed sweetpotato (TWFSF) flour was 150 gm for both, 50 gm of which included to cater for the inevitable losses.

Each child was given 500 ml of porridge in a day in two portions i.e., in the morning and afternoon. The parents of experimental children were advised not to give OFSP at home (this could interfere with the vitamin A consumption in the porridge). Otherwise the parents were advised to feed their children the normal meals at home.

RDA for zinc sulphate for this age category (3-7yrs) is 7.5mg. Since the children's diet is basically cereal and legume based in which the phytate content is definitely high, there was need to adjust the zinc sulphate amount to cater for the difference. Therefore, 15mgs of zinc sulphate solution was included in the porridge for 60 days (8weeks). The composition of the porridge for the two study groups is shown in Table 1.

De-worming and treatment of malaria and low haemoglobin levels. All the children were dewormed twice according to the procedures of the Integrated Management of childhood Illnesses (IMCI) guidelines. Children 2 years and above who had not been dewormed in the previous 6 months were dewormed using 500mg of mebendazole. They also received

malaria treatment according to the National Malaria Control Council guidelines (one and a half tablets of SP oridor were given). Those with severe anaemia were referred to the nearest health facility for treatment.

Procedure for processing flour for the porridge. The potatoes were first washed and then chipped using the potato-chipping machine at the FTC. The potato chips were then dried on canvas for a maximum of eight (8) hours. Dry chips were then milled, the flour weighed, labeled and transported to the school.

Supply of ingredients for porridge preparation. Ministry of Agriculture and Kenya industrial research institute (KIRDI) trained some local women to process the flours that were used in the study. The flours were packed in weekly portions for specific groups. Sugar, oil and zinc sulphate was bought and also supplied on weekly basis.

Preparation of the feeds. The porridge was prepared in the normal way using the usual utensils. The measurement and mixing of ingredients was however, closely supervised. The porridge was served to children at 10:30a.m. The study children (participating) ate first followed by the non-participating ones. Each child was given 500mls of porridge and supervised until each drank up all the porridge.

Monitoring for compliance. The children were made to sit down on mats in a circle. A coloured band was tied on each child's wrist to identify

Table 1: Feed components of the two study groups.

OFSP based porridge	WFSP based porridge
1. OFSP = 150gm	1. TWFSF = 150m
2. Sugar – 5gm	2. Soya bean -10gm
3. White maize – 20gm	3. Sugar – 5gms
4. Oil – 5gms	4. Oil-5gm
5. Zinc Sulphate supplementation	5. Zinc Sulphate supplementation

each of them by group. The children were again fed in the afternoon before they left for home. The teachers marked everyday against every child's name for compliance. For example, records were kept for children who were sick, those who did not finish the feed, and the reason for non-compliance also given. The feed was given 6 days in a week excluding holidays. Compliance was defined as the number of days a particular child received and drank the porridge, and was expressed as a percentage of the total number of potential porridge days.

Collection and recording of morbidity data.

Morbidity data was collected daily during school weekdays until the last day of the trial (60th day).

Collection of sweetpotato samples and the feed for analysis of carotenoids. The OFSP flour and the prepared porridge were taken to the laboratory for proximate analysis.

Quality control. The project was strictly monitored to ensure that all study procedures were adhered to. It was also aimed at providing immediate solutions to problems that arose.

Results and Discussion

Percentage distribution of age groups in the study area. Children below 14 years of age were 60.3%; while adults (15-64 years) were 39.1%. Women of reproductive age were 37.5%, while the aged were only 0.4% (Table 2).

Table 2: Socio-demographic and socio-economic results.

Age	Category	Percentage
Below 14yrs	Children	60.3
15-64 yrs	Adults	39.1
65 plus	Aged/Geriatric	0.4
15-49yrs	Women of reproductive age	37.5

Household size. The mean household size was found to be 6.05 with a median of 6.0. The minimum and maximum were 2 and 12, respectively. Compared to the National Fertility Rate (FTR) of 5.4, the household sizes in Nambale FTR were slightly higher.

Respondents. The male respondents were 49.2% (92.4 % were head of households) while women respondents were 50.8 % (7.8% of these were heads of household). Responses were mainly obtained from women.

Religion. Most families in Nambale are Roman Catholics (61%) followed by Protestants (32.7%). Among these 32.7% were males while females were 32.8. %. Muslims and Seventh Day Adventists were 3.7% and 2.5%, respectively. In all these groups women were slightly more than men.

Education. The pre-schoolers in Nambale division were 21.9%. Of these, 9.2% did not attend school. Overall, most of the people in Nambale never studied above upper primary level.

Occupation/type of work. Permanently employed adults in the study area were 3.5%. The un-employed were 32.7% while those on temporary employment were 10.0%. Most of the families in this area are farmers (25.9%). The others are artisans (1.4%), casual labourers (2.8%), teachers (1.0%) and businessmen (3.4%).

Morbidity. The causes of morbidity were reported as malaria (92%), cough (82.9%), worms (53%), diarrhoea (47%) and measles (19%). Others were: fever (17.1%), scabies (12.9%), flu (12.4%) and malnutrition (7.%) (Table 3).

Food frequency. Foods were categorized in seven groups as follows: cereals, starchy tubers/roots/fruits vegetables fruits, legumes oil/oil seeds/nuts, animal proteins, fats and oils and the miscellaneous. Among these food groups the cereals were most frequently

consumed, (54%), followed by green vegetables (31%), animal proteins mainly small fish (26.5%), fruits (23.5%) (mainly avocados) and starchy fruits/tubers/roots (23.5%) among others (Table 4).

Health and nutrition. The highest morbidity was malaria. The fully immunized children were 90.0%, while those who had received vitamin A were 90.0%. Most children had received vitamin A doses in June 2002 when the National Immunization Days (NIDS) exercise was on. The anthropometrical measurements for both the orange and the white group (weight for age and height for age) indicated a positive change.

The majority of the children had their serum retinol levels above 0.70mmol/l (Table 5). There was also no significant change in total serum carotenoids (Table 6). This was most likely due to the loss of beta-carotene during the processing of the potatoes into flour, storage and also during cooking. Most erythrocyte sedimentation rates (ESR's) were all elevated (Table 7) suggesting the presence of infection or illness with less improvement attributed to the intervention. Of all the children, 24.7% were below -2SD (HAZ), 9.4%

Table 3: Morbidity patterns in ECCD children.

Illness	Percentage
Malaria	92.4%
Cough	82.95
Worms	53.5%
Diarrhea	47%
Measles	19%
Fever	17.1%
Scabies	12.9%
Flu	12.4%
Malnutrition	7.1%
Boils	6.5%
Night blindness	2.4%

Table 4: Frequency of consumption of different foods in the study area.

Food category	Type of food (%)	Daily intake (%)	Twice per day (%)	Thrice per day (%)	Four times a day (%)
Cereals	Staple porridge	54	21.1	6.5	0
Starchy Tubers/Roots/Fruits/Vegetables	Cassava	22.4	10	0	0
Cereals	Cowpea- leaves (kunde)	31.8	2.4	0	0
Fruits	Avocado	23.5	5.9	0.6	0
Legumes/Oil Seeds/Nuts	Beans	7.1	1.2	0	0
Animal Proteins	Small Fish	26.5	4.1	0	0
Fats and oils	Kimbo	11.6	38.2	0.6	0
Miscellaneous	Sugarcane	4.7	13.5	0	0

Table 5: Effects of the daily feeding intervention of OFSP and WFSP on serum retinol levels of 170 children for 8 weeks (mean 95% confidence interval)

Serum retinol umol	Feeding intervention		P Value
	Orange group n=84	White Group n=79	
Baseline	1.00 (-1.05, +1.07)	1.08 (-1.06, +1.09)	0.6007
8 weeks	0.99 (-0.91, +1.00)	1.03 (-1.02, +1.04)	0.6437
Change	-0.01	-0.05	
Difference	- 0.05 (-0.08, +0.06)		0.8444

below -2 SD (WAZ), while 2.4% were below -2 SD (WHZ). Malaria was among the top 10 diseases reported in Nambale. Haemoglobin levels showed a shift towards improvement (Table 8) .

Nearly all the children in the two study groups had malaria parasites. During both baseline and final physical examinations a few

of the children had elevated temperatures and were treated for malaria. The study area being in a malaria endemic and vitamin A deficient zone, it was quite surprising because the serum retinol level were higher than expected. The last vitamin A supplementation in this area had been done in June 2002. The dietary intake for the households in the study suggest

Table 6: Effects of the daily feeding intervention of OFSP and WFSP on total carotenoids of 170 children for 8 weeks (mean 95% confidence interval).

Carotenoids ug/dl	Feeding intervention		P Value
	Orange group n=81	White Group n=79	
Baseline	131.36(-201.35,463.85)	127.73(-163.02, +418.48)	0.9040
8 weeks	129.32 (-124.76, +383.4)	126.18 (-177.14, +429.50)	0.4372
Change	-2.04	-1.55	
Difference	0.13(-394.98, +389.06)		0.9612

Table 7: Effects of daily feeding intervention of OFSP and WFSP on erythrocyte sedimentation rates in 170 children after 8 weeks (mean 95% confidence interval)

ESR mm/hr	Feeding intervention		P
	Orange group n=80	White Group n=79	
Baseline	23.77 (-0.91, +48.45)	23.18 (-0.19, +46.55)	0.7847
8 weeks	25.55 (-9.62, +49.48)	25.87 (-8.71, +43.03)	0.0818
Change	1.78	2.69	
Difference	0.91 (-22.87, +33.87))		3460

Table 8: Effects of a daily feeding intervention of OFSP and WFSP on hemoglobin concentration in 170 children after 8 weeks (mean 95% confidence interval).

Hemoglobin g/l	Feeding intervention		p
	Orange Group n=85	White Group n=81	
Baseline	114.53 (-112.65, +116.32)	116.80 (-116.70, +118.24)	0.3160
8 weeks	117.10 (-115.21, +118.99))	120.00 (-118.82, +121.17)	0.3429
Change	2.57	3.2	
Difference	0.63 (-0.09, +0.028)		0.2126

that the highest intake was from cereals. Vitamin A from plant sources has a problem of bio-availability and bioconversion.

Data collected on meals intake during wet and dry seasons revealed that snacks are not commonly given to children in this community, while dinner is more valued than breakfast and lunch. During dry seasons the consumption of breakfast and lunch are affected. The the number of meals reduces. The food frequency questionnaire revealed that porridge was consumed on a daily basis in many households (54%). Other foods consumed were white tea (35.5%), cowpea leaves (31.8%), kale (25.9%) and small fish (26.5%).

Conclusion and Recommendations

Until all data is analyzed, it will not be possible to conclude on the efficacy of the orange-fleshed sweetpotato porridge. However there are indications of a change towards improvement of individual children's nutrition and health status. The serum retinol levels were generally maintained throughout the study; pointing positively at the feeding intervention and the treatment of malaria and de- worming of the children. From the study, we recomend more bio- efficacy research

using the OFSP; doing a similar study in another area with the same age group; and introduction of OFSP and more food based strategies in the school feeding programmes to combat VADD.

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Vitamin A for Africa (VITAA): An entry point for promoting orange-fleshed sweetpotato to combat vitamin A-deficiency in sub-Saharan Africa

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Abstract. In sub-Saharan Africa, 640,000 children die each year from causes associated with Vitamin A deficiency. Improvement in Vitamin A intake would contribute to the Millennium Development Goal (MDG) of reducing by 20% the mortality rate of children less than five years of age. The VITAA partnership (Vitamin A for Africa) is dedicated to alleviating the suffering caused by vitamin A deficiency using orange-fleshed, beta-carotene-rich sweetpotato that meet African standards for taste and texture. A recent *ex ante* impact case study conducted by the International Potato Centre and Michigan State University suggested that 50 million children under six could benefit from the new varieties. The VITAA initiative is aimed at making orange-fleshed sweetpotatoes available on a large scale, demonstrating the potential of crop-based approaches in alleviating micronutrient deficiencies. VITAA member countries include: Tanzania, Uganda, Kenya, Ethiopia, Mozambique, South Africa and Ghana. VITAA objectives are to: complement development agencies' food supplementation/fortification efforts; increase the capacity of national agriculture, health and nutrition experts to incorporate sweetpotatoes in their national dietary recommendations; stimulate and promote micro-enterprise development using products made from orange-fleshed sweetpotatoes; teach house hold managers (women and children) the nutritional value and benefits of consuming orange-flesh sweetpotatoes. To-

date a selected number of adaptable and acceptable varieties have been disseminated to major production zones in SSA countries through non governmental organizations (NGOs) and community based organizations (CBOs), with more releases expected. VITAA strength is based on the building of partnerships with a variety of stakeholders. This paper discusses progress to date and lessons learned.

Background

Vitamin A deficiency (VAD) does not kill its victims directly. It weakens the immune system leaving them susceptible to diseases such as measles, malaria, and diarrhea. Those most severely affected are young children and pregnant and lactating women. In sub-Saharan Africa, 3 million children under the age of five suffer from a vitamin A-related form of blindness known as exophthalmia, or dry eye, and many, many more are at risk. Two-thirds of those affected may die within months due to the collapse of the immune system. Worldwide, an estimated 250 million pre-school children may be deficient in vitamin A. Public health experts believe that addressing the problem could reduce overall mortality among children under six by more almost 25 percent. Studies also show dramatic reductions in maternal mortality when pregnant women receive vitamin A or beta-carotene supplements.

Over the past 25 years, public health agencies have addressed VAD by providing children with vitamin capsules that contain mega-doses of Vitamin A. The strategy has helped millions, but has proven expensive and, despite the best efforts of those involved, has left hundreds of thousands of children at risk.

As a complement to vitamin supplements, health experts have experimented with different methods that address the problem through diet. Many types of fruits and vegetables, as well as meat and milk, are rich in Vitamin A or beta-carotene, and, if consumed in sufficient quantity can eliminate or greatly reduce the impact of VAD. Most foods that are rich in Vitamin A, however, are too expensive for African consumers, are only seasonally available, or are unpalatable to young children. The exception is sweetpotato, a highly productive food crop that has few natural enemies and is widely grown in Eastern and Southern Africa.

The experience that sowed the seeds of VITAA came in the mid-1990s, when the Kenya Agricultural Research Institute (KARI), the International Center for Research on Women (ICRW), the NGO CARE International and CIP came together in a pilot project to find out whether orange-fleshed sweetpotato would appeal to African consumers. Until then it had been assumed that few would be willing to switch from the traditional white-fleshed varieties, which are high in starch and energy and have good cooking qualities because of their high dry matter content. To our delight, the project banished the myth of consumer un-acceptability; both women and children welcomed the taste and texture of the orange-fleshed sweetpotato (OFSP). Children in particular loved the sweetness and the orange like juiciness.

On 9 May 2001, an international group of 70 agriculturists, health experts and nutritionists launched what is believed to be the first crop-based initiative to attack the tragic consequences of vitamin A deficiency in Sub-Saharan Africa. The initiative is known as VITAA, or vitamin A for Africa. Working

under the VITAA umbrella, 40 partner agencies from the health, nutrition and agricultural sectors agreed to work together to extend the impact of orange-fleshed sweetpotato in seven partner countries: Ethiopia, Kenya, South Africa, Tanzania, Uganda, Mozambique and Ghana. The VITAA goal is to create healthy rural populations through food-based approaches to nutrition focused on vitamin A.

VITAA partnership provides community groups in the SSA countries with new orange-fleshed varieties that prevent vitamin A deficiency. VITAA recognizes orange-fleshed sweetpotatoes as a promising solution to vitamin A deficiency in Eastern and Southern Africa not just because they're rich in beta-carotene, but because they're easy to grow and affordable to the average consumer. Unlike Africa's traditional white-yellow fleshed sweetpotatoes, VITAA varieties are rich in beta-carotene, a micronutrient that the body uses to produce vitamin A. VITAA is coordinated by the International Potato Center, the CGIAR research center based in Lima, Peru.

VITAA works at the community level, targeting mother's groups and other producer organizations in areas where sweetpotatoes are already grown.

VITAA OFSP varieties are rich in beta-carotene that the body uses to produce vitamin A. A recent ex-ante impact case study conducted by economists from the International Potato Center (CIP) and Michigan State University strongly suggests that 50 million African children under the age of six could benefit from the new orange-fleshed varieties. A complementary field study conducted by CIP and the International Center for Research on Women (ICRW), a VITAA partner agency, noted that in western Kenya: orange-fleshed sweetpotatoes and sweetpotato-based food products were not only acceptable to both producers and consumers in terms of appearance, taste, and texture, but contributed to the alleviation of vitamin A deficiency. The new sweetpotatoes performed well with respect to yield and pest

resistance and also had high beta-carotene content. One of the principal findings from the study was that African mothers would readily accept the new varieties, dispelling the myth that African taste preferences precluded the use of orange-fleshed varieties. The study also demonstrated that the daily addition of as little as 100 grams of OFSP to the diet could prevent VAD in children, pregnant women and lactating mothers. A major bio-efficacy study conducted by South Africa's Medical Research Council earlier this year reached similar conclusions.

VITAA currently works with collaborating agencies in Ethiopia, Ghana, Kenya, Mozambique, South Africa, Tanzania, and Uganda. Each of these countries is working hard to introduce orange-fleshed varieties, but efforts are probably most advanced in Uganda, where a host of regional organizations and NGOs are promoting the adoption of the new VITAA sweetpotatoes at the community level.

Now the partnership is capitalizing on the opportunity revealed by these findings. Adaptive research activities are being advanced in Kenya, Mozambique, Ghana, Tanzania, South Africa, Ethiopia, Madagascar, DR. Congo, Rwanda, Zambia, Malawi, Burundi and Uganda, where the NARIs scientists are working with CIP's regional staff to screen several orange-fleshed varieties in order to access their suitability to different environments. In addition, NGOs and women's groups in all countries are participating in on-farm trials, exposing a growing number of producers and consumers to their first experience of the varieties.

Farmers also found that the new orange-fleshed varieties grow well, have acceptable root yields and are moderately resistant to stresses such as drought and insect pests. Results of the assessments indicate that all varieties tested had a great potential for acceptability although the first batch was highly attacked by sweetpotato virus disease (SPVD). The variation between rankings for the various attributes both within and between agro-ecologies by farmers was not

much. The fact that OFSP varieties were liked by the consumers more so ranked high by children implies that these can be easily adopted among the farming communities in Africa. Markets of OFSP (roots, processed chips and vines) and multiplication and distribution of planting materials have continued to rise as a result of individual farmers' and community-based organizations' efforts. For instance, in Western Kenya, more than 18 million vine cuttings mainly of OFSP varieties have been distributed to farmers through partners in the region.

Potential of orange-fleshed sweetpotato in combating Vitamin A deficiency in SSA. The promotion of orange-fleshed sweetpotato is showing great promise as a key element in strategic partnerships to solve the problems of malnutrition and food insecurity in eastern and southern Africa. Sub-Saharan Africa (SSA) is the only region in the developing world where both the number and proportion of malnourished children has been consistently rising. According to projections in IFPRI's 2020 Vision project, the number of malnourished children is projected to rise from 33 million in 1997 to between 39 and 49 million in 2020, depending on the model used (Rosengrant *et al.*, 2001).

In SSA, three million children under the age of five suffer total or partial blindness caused by Vitamin A deficiency (VAD). Vitamin A is consumed directly in meat products, and is produced in the body if a person consumes sufficient quantities of a precursor known as β -carotene. Otherwise, the body cannot produce sufficient Vitamin A. Vitamin A deficiency is particularly a problem among children under five and pregnant and/or lactating women. Serious VAD can lead to blindness; chronic deficiency reduces a child's immune system to fight off malaria and other diseases

Development and health agencies have reacted to this crisis by distributing Vitamin A capsules and fortifying processed and packaged foods. The results have been impressive. More than 12 million children

received Vitamin A supplements in 1997, and the total number of children suffering from blindness related to severe vitamin A deficiency has dropped. Nevertheless, many families, particularly in rural areas, do not have access to capsules or fortified foods. In these areas therefore, Vitamin A chronic deficiency is rife. In circumstances where use of capsules and fortified foods to mitigate the situation is not possible, the use of orange-fleshed sweetpotatoes seems feasible. Sub-Saharan Africa produces over 7 million tons of sweetpotato annually, about 5 percent of global production. Recent projections indicate that production will more than double by 2020, whereas production in other regions is expected to remain stable or take decreasing trends. Sweetpotato is an important household food security crop in eastern and southern Africa, particularly in densely populated, intensively cultivated mid-elevation farming areas. Although the crop is mainly cultivated for domestic consumption, both fresh roots and leaves are increasingly gaining market potential for cash income. Roots are commonly consumed fresh, mostly just boiled or roasted, and the range of common recipes is narrow. Most sweetpotato varieties grown in Africa have white- or yellow-coloured flesh, and supply little or no Vitamin A. Orange-fleshed varieties introduced from other parts of the world or bred locally have been readily accepted in pilot areas in East Africa, and preliminary results have shown that they contain sufficient levels β -carotene to play an important role in eliminating VAD (Hagenimana *et al.*, 1999).

Ex-ante impact study. An impact case study conducted by economists working at Michigan State University and CIP suggests that orange-fleshed sweetpotato could significantly help prevent vitamin A malnutrition in sub-Saharan Africa and could eventually benefit some 50 million African children.

According to the study, in countries such as Rwanda, Burundi and Uganda, where sweetpotato production is already high, full

adoption of orange-fleshed sweetpotato could resolve vitamin A deficiency completely for 85 to 95 % of children most at risk in addition to significant benefits for childbearing women.

Even in countries that are not major sweetpotato producers, such as Ethiopia, a third of the population would enjoy partial benefits from enhanced beta-carotene intake as a result of switching from white- to orange-fleshed varieties.

Fortification of food crops such as sweet potato with higher levels of micronutrients – a process known as bio-fortification can be a powerful tool in combating nutritional deficiencies. However, there is a lot of optimism that it will benefit large numbers of people in the years to come. IFPRI and the International Center for Tropical Agriculture, head HarvestPlus, a new CGIAR initiative working to fortify major developing country staples, such as beans, cassava, maize, rice, wheat, and sweetpotato. The VITAA experience serves as a model for these efforts, providing concrete evidence of the effectiveness of food-based approaches in tackling micronutrient malnutrition.

Adaptive research on orange-fleshed varieties. A series of adaptive research and pilot extension activities have been conducted to provide the project with information in several key areas. To-date the stage for large-scale diffusion of the new varieties has been set with the target of scale-up by 2005. Activities done in collaboration with farmers mainly women groups include: a) studies that further define role of the new varieties in the family diet; b) efforts to establish micro-enterprises and micro-credit schemes; c) the testing of on-farm processing techniques, including the enrichment of local weaning foods; d) pilot testing of rural seed multiplication and distribution systems, and e) the provision of superior breeding lines. To-date ten to twenty OFSP varieties with high dry matter have been accepted consumers in the region. Fourty new clones

are being tested widely in all VITAA partner countries for adaptability and acceptability

Before the VITAA initiative, it had been assumed that few consumers would be willing to turn away from the traditional white-fleshed varieties, which are high in starch and energy and have good cooking qualities because of their high dry matter content. To our delight, the OFSPs were acceptable to both adults and children. Children in particular loved their sweetness and the orange like juiciness.

The partnership is now capitalizing on the opportunity revealed by these findings. Adaptive research activities are being advanced in Kenya and Uganda, where KARI and the National Agricultural Research Organization (NARO) scientists are working with CIP's regional staff to screen several orange-fleshed varieties for their suitability to different environments. In addition, NGOs and women's groups in both countries are participating in on-farm trials, exposing a growing number of producers and consumers to their first experience of the varieties. A number of orange-fleshed varieties are currently being multiplied and cleaned for viruses by CIP at Muguga Plant Quarantine Services in Kenya for distribution to different sub-Saharan countries.

In Luwero district Uganda, children loved the taste, texture, and color of *Ejumula*, a deep orange variety, while adults preferred the lighter orange *Kakamega* variety, which is less sweet and has much appealing flavour. Additionally, these varieties grew well, had acceptable tuber yields were moderately resistant to stresses such as drought and insect pests (CHDC, 2001). These results imply that these varieties can be easily adopted in Luwero. According to children, *Ejumula* had a very attractive color, sweeter and less fibrous whereas for the adults, the most preferred variety was '*Kakamega*' (SPK004). It was flourier and not sugary like *Ejumula*. Field attributes like resistance to pests, drought tolerance and time to maturity were ranked high by the farmers. Similarly, all varieties were ranked above moderate for the

tuber yield attributes. Throughout the five villages where the study was done, *Ejumula* and *Kakamega* (light orange/cream) were the most preferred varieties.

In addition to the above, farmers in Kenya, Tanzania and Uganda have evaluated other orange-fleshed and other preferred varieties.

Principles of the VITAA Work Plan. As a result of these highly promising results, representatives from the seven VITAA partner countries have agreed to promote orange-fleshed sweetpotato in each of the major production zones where white-fleshed varieties are most dominant. The work is mainly community-based and focuses on women decision makers. It also emphasizes nutrition education and micro-enterprise development. The partnership operates according to the following principles:

1. That orange-fleshed sweetpotatoes are now acceptable by African consumers and ready for full-scale development, and will also prove effective as an entry point for other food-based strategies aimed at reducing VAD in sub-Saharan Africa.
2. That VITAA varieties can empower local communities to help mothers and young children prevent VAD through their own labour and industry but also increase their incomes through value addition.
3. That VITAA provides a highly effective tool to address VAD among rural poor communities more especially children, pregnant women and lactating mothers.
4. That evidence exists that the VITAA varieties may also help to reduce the impact of anemia, measles, and malaria.

VITAA Agenda. VITAA's agenda consists of a coordinated set of activities in the major sweetpotato-producing countries of Eastern and Southern Africa. Its principal objective is to promote wide-scale production and use of

orange-flesh sweetpotato. The partnership program focuses on Uganda, Kenya, Ghana, Tanzania, South Africa, Mozambique and Ethiopia. Close linkages are also maintained with partner institutions in other countries through two regional root and tuber crops research networks: PRAPACE (ASARECA) and SARNET (SACCAR). Project activities include: ex-ante impact assessment, participatory testing of varieties for adaptation and acceptability, community-based multiplication of planting materials, nutrition education, post-harvest processing for market and for home consumption, promotion through social marketing, monitoring of impact on nutrition and health, and capacity building. Principal beneficiaries are young children and their mothers, the two groups most at risk for Vitamin A Deficiency or VAD. Implementation strategies concentrate on women because of their central role in the production and marketing of sweetpotato and other food crops used in the family diet. Country work plans have been developed with key stakeholders to identify interventions with the highest potential pay-off.

VITAA Action Points. To make VITAA technology ready for full-scale deployment over the next five years, the partnership members have organized themselves around the following six-point action plan:

1. The establishment of a steering committee from all sectors of the Partnership. To-date, members include the Micronutrient Initiative, the International Center for Research on Women, the non-governmental organization Catholic Relief Services and CIP, along with one member from each participating country;
2. The development of national action plans. These include issues on health, nutrition and agriculture;
3. The development of a comprehensive, integrated regional action VITAA;
4. The completion of an efficacy and bio-availability study to confirm the uptake and efficiency of beta-carotene from sweetpotato for conversion into vitamin A in the body;
5. The establishment of communication and social marketing strategies to promote and increase the utilization of VITAA varieties. The envisaged outputs for VITAA include:
 - (i) Sweetpotato varieties with good agronomic and nutritional traits plus local acceptance;
 - (ii) Sustainable local seed multiplication and distribution systems;
 - (iii) Processed products based on new varieties;
 - (iv) Microenterprises based on OFSPs;
 - (v) Community- and household-based action plans for combating VAD with OFSPs;
 - (vi) Partnerships of trained of trained professionals committed to OFSP food-based approach to VAD;
 - (vii) OFSP information systems and databases;
 - (viii) Public education; and,
 - (ix) Monitor and and evaluate all project activities and measure impact.

Impact Assessments, Monitoring and Evaluation. The IFPRI-CIP study completed in 2001 revealed that there is sufficient per capita production of sweetpotato in SSA. And as such, the introduction and diffusion of OFSP varieties is most likely going to have positive consequences for vitamin A deficient populations. From this study, up to 50 million children in the region could benefit significantly from the new OFSP varieties.

Planning and Constituency Building. Working from the results of the ex-ante assessment, project leaders have embarked on a program of constituency building. The objective is to garner support for the use of high vitamin A sweetpotato among national policy makers, as well as NGOs and development agencies working in agriculture, human health, and nutrition. This is intended to create dialog on how best to exploit the new varieties, determine where they complement existing nutrition programs, and chart out a course for their full exploitation.

Training. The sustainability of the initiative, following the research and implementation phase, can only be assured by building local capacity to exploit the new technologies. To the greatest extent possible, training programs have been and continue to be conducted in all major project areas, including impact assessment, seed multiplication, post harvest processing and marketing, micro-enterprise and micro-credit. Priority has always been given to the concept of training of trainers.

Social Marketing. To encourage adoption of new technologies, VITAA has also developed a social marketing strategy and action plan. Mothers and school-age children have been targeted with messages that create demand for the new varieties and associated food products. The social marketing component has also encouraged government, NGOs, and community-based organizations to take responsibility for the distribution of the high beta-carotene materials and for micro-enterprise development.

Selected key success stories from the fields: A case of Uganda

Innovation to tap high demand for orange fleshed sweetpotato program. *Nju ku Nju* literally meaning “house to house” is a code name of a program by Mr. Hakim Ssali, a resident of Kayunga district in Uganda, where he moves from house to house sensitizing farmers on the importance of OFSP. He ultimately sells the vines to farmers who get interested. Hakim picked interest in OFSP from his friend Mr. Rajab Setyabula a prominent progressive farmer from Luwero district.

Consequently, a promotion campaign in Kayunga town council was launched. Many people got interested and an estimated 30 bags each containing 900 vines were sold to farmers, schools, and a prison. By the end of 2003, sensitization and distribution of planting materials had covered 5 sub-counties in Kayunga district and 4 sub-counties in the neighbouring Mukono district. In 2004 the

program was extended to Jinja and Kamuli districts.

The working strategy is to sensitize farmers about the potential benefits of OFSP and encourage them to start growing them. While moving house to house Sali carries along planting materials, which are sold to interested farmers. To encourage and make it affordable for most farmers only 45 vines are sold at U.shs 500= .30 cents of US \$. These vines are sufficient to plant only 15 mounds. However, there are framers who get interested and can afford to buy more vines to establish bigger fields. These are allowed to buy a full bag of vines at U.shs 10000= US \$ 6. The bag contains 900 vines which are sufficient to plant 300 mounds of a garden. After two months, “Nju ku Nju” goes back and buys planting materials from the farmers who started with a bag of vines. These are expected to produce over 20 bags of vine cuttings. The program strategically buys only 18 bags from the framers leaving the balance for more multiplication. At this time a farmer is paid U.shs 5.000/ per bag, thus getting a total earning of U.shs 90.000. The program sells these vines to the new farmers visited, and earns U.shs 180.000. This is the money he pays transport costs and other requirements for the program to run before getting a profit margin. Meanwhile the farmers who started with 45 vines will generate a minimum of 900 vines at the end of the two-month period and are at this time advised to expand their multiplication beds. They can benefit from the purchases of the vines by the program after second round of multiplication.

Using hired motorcycles, two farmers have been able to traverse many villages in the operation area. They move along with fresh roots, flour and juice samples as well as education materials like calendars, and posters. They have opened location offices in different districts, which serve as physical contact addresses as well as stores for planting materials.

With this strategy Mr. Hakim has achieved a lot. Though without proper records, Hakim estimates to have sensitised over 10,000

farmers. Through the profits he has made, he has purchased a 2 acre piece of land and meets school fees for his children. Many other people have benefited from the initiative. He estimates that about 40 farmers have already benefited selling planting material to him while are a lot more now eat orange fleshed sweetpotato in their households. He is also more hopeful since his initiative has attracted attention and interest from the office of the Special Presidential Assistant for the Underprivileged Youth.

Farmers train fellow farmers in OFSP production and utilization.

Mrs. Joweria Sekiyanja is proud of her achievements during the year 2004. Her face beams with a smile as she narrates the achievements. “Last year I told you that I had paid schools fees for one of my children during one the school terms, but I have been able to pay school fees for four children throughout 2004” boasts Joweria. “As a wife who was entirely depending on my husband I feed proud for having made this” says a jolly Joweria. “I have began building a commercial house on the plot I bought last year using money from sales of sweetpotato fresh roots, vines as well as products” says Joweria. According to records available her group has sold planting materials worth over Ugshs. 19 millions (equivalent \$11,100). She locally processes and sells juice, doughnuts, pancakes and cakes out of sweetpotato on a daily basis, an activity she says earns her at least Ughs. 5000 as profit daily. “I have opened a savings account on which I deposit at least shs. 1000 per day” says Joweria. Similar gains have been made by other women in her group and she believes that OFSP activities have improved livelihoods of many women in her village.

Joweria attributes the achievements to a number of factors. First she worked hard to expand her fields to 5 ha a decision she took at the beginning of the year. Second, she has participated in a number of workshops and exhibitions during which she has made contacts with key partners. These include: workshop for Jinja district members of

parliament. National Agricultural Shows in Jinja, World Food Day celebrations in Masaka, National Trade show at Lugogo, and the Launching of Poverty reduction program by the president at Katoke Luwero.

“The workshop for Parliamentarians was important for me. Many MPs especially women MPs got interested in my work and later contacted me to train their women groups in their respective areas” Says Joweria. According to her records, she has trained over 30 groups on request of members of parliament and other organizations. “We also got a juice sieving machine as a prize during the national trade show”, she reported. Recently she had yet another important opportunity where she interacted with the President of Uganda when he was launching a poverty reduction program in Katoke, Luwero. “The president spent 30 minutes asking me about the number of products I had exhibited despite a hurry move he made through other exhibitions” Joweria says with pride. She further asserts that the President later referred to and praised her work during the public address speech. The president then promised them a factory to expand on sweetpotato processing. She is hopeful that she will be successful because of the immense opportunities available.

Rural processing of orange-fleshed sweetpotato for food and income.

Mr. Ekinyu Eugene is the chairman of a rural processing group based in Abuket village, in Soroti district, North Eastern Uganda. The group is called “Abuket Orange-fleshed Sweetpotato Processors Association”. He acknowledges that he and his group are much better off since they began processing dried sweetpotato chips. His group was born out of a farmers’ group originally supported by an NGO, SOCADIDO, in sweetpotato production. They were experiencing yield surpluses but had limited markets. To avoid wastage, they would process sweetpotato using traditional means into *Amukeke*. However, the *Amukeke* had quality problems. Sweetpotatoes used to be sliced using traditional knives into big

slices that took long to dry and would therefore get mouldy. They were also dried on the ground resulting into a poor quality product. In addition, big slices were susceptible to storage weevils. To solve the above chain of problems, CIP together with its partners (particularly NARO and SOCADIDO) decided on piloting the rural based processing units made of groups with inteprenual interests and experiences. Thus Ekinyu's group was one of the two groups identified in Soroti district. The groups were trained in various aspects of quality processing and control of dried sweetpotato chips. A motorized chipper mounted with blades to slice sweetpotato into small chips that dried quickly was donated to the group through SOCADIDO during the launching of OFSP in Soroti district. The group went ahead and began processing sweetpotatoes into high quality chips. The group's first tone of dried chips was sold to Maganjo Grain Millers Co.

Women demand for “Babies Food” - orange fleshed sweetpotato in Hoima. Women in Hoima district are all out looking for a sweetpotato type called “Kirisabaana”. The word “Kirisabaana” is a term in the local language meaning “ that feeds children”. In Hoima district, the orange-fleshed sweetpotato were introduced through Bulindi Agricultural Research and Development Centre, a National Agricultural Research Organization (NARO) zonal institute. The Centre Manager of the Intitute reported that the promotion of orange fleshed sweetpotatoes was the institute's first success story. He also reported that in collaboration with Hoima District Farmers' Association, OFSP were very successssful in the distrct , that they ahd even spread to neighbouring districts.

VITAA Scoops A 2003 CGIAR Partnership Award. VITAA with its partners, has managed to introduce and popularise OFSPs in the region. During the 2003 Annual General Meeting of the Consultative Group on

International Agricultural Research (CGIAR) held in Nairobi, this VITAA effort was recognised. In this meeting, partners represented by individuals from Kenya and Uganda received the prestigious CGIAR award for the outstanding partnership and efforts to alleviate Vitamin A deficiency in Sub Saharan Africa.

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Time of harvesting and its effect on the quality of flour from four cassava varieties

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Abstract. Four varieties of cassava (*Afisiafi*, *Tek bankye*, *Abasafitaa* and *Gblemoduade*) were harvested each month from 9 to 15 months after planting and processed into flour. The yield of flour and some of its physicochemical properties were studied to determine how they were affected by harvesting time and varietal difference. The properties of flour studied were: moisture, ash, crude protein, crude fibre, pH, swelling power, solubility, starch yield, amylose content and pasting characteristics. *Afisiafi* and *Tek bankye* both had their peak flour yields (23% and 22.4% respectively) at 13 months after planting while *Abasafitaa* and *Gblemoduade* had their peak flour yields (23.4% and 20% respectively) at 12 months after planting. Both *Afisiafi* and *Tek bankye* had flour yields increasing uniformly from 11 to 13 months after planting after which they fell while *Abasafitaa* and *Gblemoduade* had their flour yields increasing from 9 through 12 months after planting after which they fell. Moisture content ranged between 6.3% and 14.6%, while ash content was between 0.70% and 2.21%. All flour samples had pH ranging between 5.07 and 6.65 indicating unfermented flour of high quality. All the varieties had a minimum crude protein content of 0.22%; *Afisiafi* and *Tek bankye* had maximum values of 1.53% and 1.68% respectively at 9 months after planting while *Abasafitaa* and *Gblemoduade* had maximum values of 1.68% and 1.53% respectively at 15 months after planting. Starch yield was between 53.60% and 76.01% while solubility ranged between 7.81% and 18.80%. Age significantly affected ($p < 0.05$) flour yield, crude protein, ash and moisture, while pH, crude fibre, amylose and swelling power were neither affected significantly ($p > 0.05$) by age nor variety. Starch yield of flour, solubility, ash content and pasting characteristics were all significantly affected ($p < 0.05$) by variety. *Afisiafi* and *Tek bankye* had higher peak viscosities than *Abasafitaa* and *Gblemoduade*. Both hot paste stability and hot paste breakdown were highest for *Gblemoduade* and lowest for *Abasafitaa*. *Afisiafi* and *Tek bankye* had higher retrogradation while that of *Abasafitaa* and *Gblemoduade* were close to zero.

Genome organization and molecular variability in Sweetpotato chlorotic fleck virus

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Abstract. The complete nucleotide sequence of the genomic RNA of a Ugandan isolate of Sweetpotato chlorotic fleck virus (SPCFV) was shown to be 9104 nt. The SPCFV RNA not only is very similar in genomic organisation to that of carlaviruses but also encodes proteins that showed strong homologies with those of carlaviruses. Open reading frame (ORF) 1 codes for a 238 kDa protein with characteristic motifs of replication-associated proteins. ORFs 2, 3 and 4 code for proteins of 27.5, 11.5, and 7.3 kDa, respectively, that form the multifunctional triple gene block proteins. ORF 5 encodes the capsid protein (CP) of 33 kDa and ORF 6 a 15-kDa protein with a nucleic acid binding zinc finger motif (NBP). Comparison with other carlaviruses showed 12-40% similarities. Based on CP sequences, the closest relatives of SPCFV among carlaviruses are Shallot latent virus (36.2%) and Kalanchoe latent virus (37.1%). However, the SPCFV genome (9.1 kb) differs from typical carlaviruses (7.4 - 8.5 kb) by being considerably larger as a result of a larger ORF 1 (238 vs. 200-223 kDa) and a long untranslated region between ORF 4 and 5 (213 vs. ca. 34 nt for Potato virus M). To obtain a better understanding of the molecular variability of the SPCFV genome, about 2000 nts of the 3' terminal genome part of a range of geographically diverse isolates were sequenced. Comparison of the deduced amino acid sequences revealed a considerable level of geographically associated diversity among SPCFV isolates. The CP and NBP amino acid sequence similarities ranged from 88 to 100 % and from 75 to 99%, respectively. In phylogenetic analysis of CP amino acid sequences, a major East African cluster with 92-99% intragroup identity and a non-East African cluster with 88-91% intragroup identity became evident.

Soil nutrient and cassava yield variations under continuous cultivation of three-crop mixtures in Eastern Nigeria

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Abstract. A research farm at UNN which was under cultivation for >25 yrs before it was fallowed for 8 yrs, was cleared in 1998 and grown to three common crop mixtures for four years. The aim was to assess the performance of the cassava component under continuous cultivation relative to soil nutrient variations. The crop mixtures were cassava + pigeon pea, cassava + pigeon pea + maize, and cassava + pigeon pea + maize + yam. Incorporation of crop residues from each of the respective plots into the soils and the use of a legume (pigeon pea) served as means of restoring soil fertility. The experimental design was a randomized complete design (RCBD) replicated thrice each year. Changes in eight selected soil fertility indicators were monitored for the period. An analysis of the nutrient contents in the soils under the crop mixtures indicated narrow variations over the four years except in the cases of exchangeable cations where coefficients of variations of >25% were obtained. Comparatively, year-to-year variations were more substantial though not consistent. This is because in some years some nutrients decreased while others increased relative to the values obtained in the preceding year. Except in 1999 when cassava root yields from all the crop mixtures decreased substantially (>60%) relative to their 1998 respective values, the trends in other years were not consistent in all the crop mixtures. The mean yields obtained were generally below the expected mean yield for the same cassava variety in the area. The study also showed that all the soil parameters selected contributed to the variations in cassava yields though they were not consistent in each year and in each crop mixture. Thus, adequate management of these soil factors is required to enhance the performance of cassava in the crop mixtures.

Seed yam marketing in Nigeria: Determinants and constraints

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Abstract. Seed yam marketing in Nigeria is gaining recognition not only as an income generating enterprise but also in replenishing the stock of planting materials among yam farmers. This study examines the seed yams marketing in Nigeria, its determinants and constraints. Data collected were analysed using descriptive techniques and ordinary least square regression framework to identify the determinants of the quantity of seed yam traded. Results showed that males and females are proportionately engaged in this business. About 55% of the marketing agents were males while 45% were females. Volume of seed yam traded is determined by literacy level, marketing experience and the manner of displaying seed yam in the market. Limited

capital endowment, high cost of transportation and limited storage facilities constitute major constraints in seed yam marketing in Nigeria. Provision of cheap and easily accessible sources of credit, and improvements in market access and storage facilities will enhance marketing efficiency and provide incentive to marketing agents.

Characterization and variability of sweetpotato virus Y, a hitherto unrecognized potyvirus infecting sweetpotato in Southern Africa

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Abstract. The biological and molecular properties of a sweetpotato virus isolate formerly known as sweetpotato virus 2 were determined. The virus had flexuous filamentous particles, induced cylindrical inclusions in infected cells and was experimentally transmitted by *Myzus persicae*. Sequence analysis of its coat protein and 3' non-translated region revealed that the virus is a distinct potyvirus, for which the name Sweetpotato virus Y (SPVY) is proposed. *Sweetpotato chlorotic stunt crinivirus* (SPCSV) synergized SPVY in *Ipomoea setosa* in mixed infections. Unlike plants that were infected only with SPVY or a Kenyan isolate (KY-38) of SPCSV and largely showed no symptoms, dually infected plants had significantly higher titres and a more uniform distribution of SPVY and showed conspicuous symptoms of SPVY infections. Comparisons of coat protein CP gene sequences of geographically diverse isolates of SPVY revealed amino acid sequence identities ranging from 86 to 100%. The results strongly suggest the existence of biologically and genetically diverse strains of SPVY from Southern Africa.

Evaluation and promotion of orange-fleshed sweetpotato to alleviate Vitamin A deficiency in Orissa and Eastern Uttar Pradesh of India

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Abstract. Sweetpotato is the most important crop next to cereals in Orissa and plays an important role in the agrarian economy of the state. A ready and cheap source of beta-carotene is the orange fleshed sweetpotato, which contains high amounts of beta-carotene, largely responsible for the orange color of the flesh. Vitamin A deficiency can be prevented in children when there is regular intake of 100g of orange fleshed sweetpotatoes everyday. The International Potato center (CIP) had introduced the orange fleshed sweetpotato germplasm CIP 440074 along with other materials like IB-90-10-20, CIP 440127 and CIP-SWA-3 in the Gajapathi, Ganjam districts of Orissa and Gorakhpur district of eastern Uttar Pradesh(UP). CIP-440074 recorded highest yields at all the three locations both in terms of market and fresh root yields. The yield of local varieties at all the three places, when compared with the CIP cultivars was significantly low. Apart from CIP-440074, the cultivar CIP-440127 recorded the second maximum yield at all the three places both in the case of market and fresh root yields. CIP 440074 is very popular in the eastern UP and is ready to be released as a variety in this region because of its high yield and orange color of flesh. High risk of Vitamin A deficiency in the above regions should be reduced by wide cultivation of the orange fleshed sweetpotatoes. The above varieties performed well and should be promoted.

Introduction

Sweetpotato is an important crop in South Asia. Sweetpotato production in the region is about 1.6 million tons on 0.2 million hectares. India accounts for 68% of the total production followed by 27% in Bangladesh and about 5% in Sri Lanka. Sweetpotato is the most important root crop in Bihar and Orissa covering 17,900 ha and 47,900 ha with a production of 170,700 ton and 364,900 ton respectively. It is also an important root crop in Uttar Pradesh covering 30,600 ha with a production of 285,900 ton. It can be grown in poor soils but also performs well in a fertile environment, far exceeding yields of cereal crops. Sweetpotato can be grown with limited land, labour and capital. Early maturing sweetpotato varieties provide higher edible energy per unit area and unit of time than all other major food staples. The tender leaves of sweetpotato vines can be eaten as a vegetable. However, a major use of the leaves, is for animal feeds, particularly for dairy cattle and goats.

Dietary vitamin A deficiency is the world's most common cause of childhood blindness. The world Health Organization (WHO) estimated that as many as 228 million children worldwide are affected subclinically at a severe or moderate level by vitamin A deficiency. About 3 million of these children have some form of vitamin A related eye

disease, ranging from night blindness to irreversible partial or total blindness. Every year, at least 500,000 children become partially or totally blind as a result of this deficiency. Vitamin A deficiency (VAD) causes an estimated 30,000 to 40,000 children in India to go blind each year. Prevalence of vitamin A deficiency rates vary greatly among the states and ranges from 2.2% in Andhra Pradesh to 9.0% in Bihar. Prevalence of VAD is a significant public health problem in India.

A ready and cheap source of beta-carotene is the orange-fleshed sweetpotato, which contains high amounts of beta-carotene (Simonne *et al.*, 1993; Takahata *et al.*, 1993). A regular intake of 100g per day of orange-fleshed sweetpotato roots provides the recommended daily amount of vitamin A for children.

Materials and Methods

Batches of sweetpotato germplasm were introduced in the districts of Ganjam, Gajapathi in Orissa and Gorakhpur in Eastern Uttar Pradesh. Accessions were also acquired from farmers' fields in the above three districts. The

corresponding soil types in the districts are given in Table 1. All the materials were screened at the CIP Regional office farm in New Delhi for over two seasons (Table 2). Seven selection based on fresh root yield were made from these trials.

Evaluation trials. Multi-locational trials at three districts in different agro-ecologies were conducted over two seasons in progressive farmers' fields. Seven selections were grown along with the local variety in the three districts. Based on the results of the multi-locational trials, four selections were made on the basis of fresh root yield. The four selections were evaluated in farmers' fields in the three districts.

Results and Discussion

The highest fresh root yields from the multi-locational trials were recorded in the three districts (Table 3). The four cultivars selected were CIP- 440127, IB-90-10-20, CIP- 440074, CIP-SWA-3. The highest root yields were obtained from Ganjam and Gorakhpur districts. CIP-440074 recorded highest yields at all the

Table 1: Districts and Agro-ecologies of the evaluation trials.

Name of the districts	State	Soil type
Ganjam	Orissa	Sandy-loam soils
Gajapathi	Orissa	Red Sandy-loam soils
Gorakhpur	Uttar Pradesh	River bed loamy soils

Table 2: Performance of the seven local cultivars at the CIP Regional office, New Delhi.

Cultivar	Market root yield (t/ha)	Fresh root yield (t/ha)
CIP-440127	20.7	24.8
IB-90-10-20	17.5	22.9
CIP-440074	22.4	30.1
CIP-SWA-7	16.8	21.2
CIP-SWA-3	19.1	22.4
CIP-SWA-1	12.2	18.2
IB-97-12-7	18.9	21.7
Mean	18.22	23.04
CV	17.86	16.04

Table 3: Performance of 4 cultivars in relation to local variety in various districts.

District/cultivar	Market root yield (t/ha)	Fresh root yield (t/ha)
<i>Ganjam</i>		
CIP-440127	21.2	27.8
IB-90-10-20	16.5	22.3
CIP-440074	26.8	32.3
CIP-SWA-3	21.2	28.4
Local	12.1	17.1
<i>Gajapathi</i>		
CIP-440127	23.4	28.2
IB-90-10-20	20.9	23.2
CIP-440074	24.8	31.0
CIP-SWA-3	19.1	23.2
Local	14.4	16.4
<i>Gorakhpur</i>		
CIP-440127	19.1	30.8
IB-90-10-20	21.4	29.2
CIP-440074	28.3	37.7
CIP-SWA-3	22.1	27.2
Local	16.4	19.1
Mean	20.51	26.26
CV	21.64	22.69

three places both in terms of market and fresh root yields. The maximum fresh root yield was recorded for CIP-440074 at 37.7 t/ha in the Gorakhpur area. The yield of local varieties when compared with the CIP cultivars was significantly low. Apart from CIP-440074, the cultivar CIP-440127 recorded the second maximum yield at all the three places both in the case of market and fresh root yields. IB-90-10-20 recorded high at Gorakhpur area both in terms of market and fresh root yields when compared in Ganjam and Gajapathi districts. CIP-SWA-3 also recorded maximum market and fresh root yields at Gorakhpur district when compared with the local variety. The local varieties yields at the three places were on par with each other ranging from 12.1 t/ha to 19.1 t/ha. The variation in terms of yield was not much significant among the CIP cultivars. CIP- 440074 is more preferred by

farmers in Ganjam, Gajapathi and Gorakhpur districts because of high yield, carotene and the moderate starch content.

Vitamin A deficiency in Orissa Orissa is the largest sweetpotato growing state in India (Table 4). In Orissa, 60% of the population lives below the poverty line and 53% is malnourished. Overall prevalence of Vitamin A deficiency is 0.2% in the country but in Orissa vitamin A deficiency occurs in approximately 0.9 % of the population (Rajalakshmi, 2001). Orange fleshed sweetpotatoes were a potential food substitute to the tribesmen living in the state of Orissa.

Vitamin A deficiency in Gorakhpur (Uttar Pradesh) India. It is estimated that the prevalence of vitamin A deficiency at

Table 4: Area, production and productivity* of sweetpotato in leading states in India.

State	Area (x 1000 ha)	Production (x 1000 mt)	Productivity (t/ha)
Orissa	43.9	361.2	8.2
Bihar	9.9	135.2	13.7
Uttar Pradesh	25.6	302.1	11.8
Assam	8.9	31.0	3.5
Karnataka	3.1	23.3	7.5
Kerala	1.1	11.9	10.8
Tamil Nadu	1.9	32.2	16.9
India	114 (total)	1007 (total)	8.8 (average)

* Source: Indian Horticultural Data base – 2001(National Horticulture Board- Gurgaon, India)

Gorakhpur is 10.97% (Sharma, 1985) and it was most prevalent among children of 3-5 years of age. Gupta (1987) estimated the prevalence of vitamin A deficiency in different child age groups at Gorakhpur, based on hospitalized children (Table 5). Night blindness, conjunctival xerosis, Bitot's spot and active corneal involvement were found in 5.5 %, 15.74 %, 4.72 % and 14.9% of children respectively. Kansal (1997) studied the prevalence of vitamin A deficiency among rural and urban population at Gorakhpur. Overall prevalence of vitamin A deficiency was 6.8 % in children under 5 years of age and it was more prevalent in rural areas (9.3%) than urban areas (3.1%). CIP 440074, which is orange-fleshed, was found to be promising in terms of yield in the Gorakhpur area.

Implications

Farmers use local cultivars, which have poor yields and hence less economic benefits to the resource poor farmers. Introduction of exotic lines with high β -carotene and relatively high dry matter content should improve the economic status of the people in this region in addition to alleviating the vitamin A deficiency. Production of orange fleshed sweetpotatoes should be promoted and integrated with a processing industry ease processing and also to produce high quality sweetpotato products.

Table 5: Distribution of different age groups suffering from vitamin A deficiency at Gorakhpur.

Age group	Children suffering from vitamin A deficiency
2 months-1 year	10%
1-2 years	43.3%
2-3 years	45.8%
3-4 years	61.9%
4-5 years	53.8%
5-6 years	55.3%
Average	40.9%

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Use of fluorescent *in-situ* hybridisation to investigate possible involvement of *Clostridium* spp. during softening and fermentation of cassava

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Abstract. This study was designed to investigate the possible role of *Clostridium* spp. in softening of cassava, using a novel molecular method “fluorescent in-situ hybridisation” (FISH). The technique can be applied directly to fermented cassava, and is used in parallel with conventional cultural isolation techniques. The use of FISH has been proposed to validate the results of cultural techniques and to determine the presence of components of the microflora that were not previously recovered. Peeled and unpeeled cassava pieces were incubated at 40°C, 37°C, 30°C and 25°C for 5 days. Compiled results of current and previous *in vitro* model cassava fermentations, demonstrated large variations in the extent of softening during fermentation. In the most recent study, however, the fermentation did lead to cassava softening. Although low numbers of presumptive *Clostridium* spp. were recovered using conventional cultural methodology, results obtained using the FISH technique failed to demonstrate the presence of this bacterium. It was concluded that, while there is some evidence for the presence of *Clostridium* spp. in cassava fermentations, further work on the methodology of FISH assays is required. Possible reasons for the failure of the technique to detect Clostridia are discussed.

Pasta production: Another under-exploited way of increasing cassava utilization

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Abstract. One of the contributory factors to low cassava utilization, despite its promising potential, has been attributed to limited utilization options. Whereas one area has been cited as poor utilization in the fresh state in the form of *kibabu*, other potential options have not been exploited fully in Tanzania. This study was conducted to establish possible levels of blending wheat flour with cassava flour, soybean flour or cassava starch, singly or in combination, to produce acceptable pasta and assess its acceptability. Wheat flour was used at a level not lower than 50% in the formulations. Also in each of the formulations, soy and cassava flour or cassava starch were used at 5, 10, 15, 20, 25, 45, and 50%. Results showed that it was possible to produce pasta from simple household Italian pasta making machine with all formulations except those with 45% or more of soy flour. All formulations with less than 80% wheat flour easily broke into small pieces, the extent of which depended on their composition, even prior to cooking. To produce cassava-based pasta, it was easier to work with the flour than pure cassava starch. The samples with 50:45:5 wheat:cassava starch:soy became porridgelike after cooking. Sensory evaluation results showed that pure wheat pasta was significantly ($p<0.05$) more accepted than the remaining formulations in terms of colour, smell, taste, texture and general acceptability. The sample with 20% cassava inclusion was the next most preferred. Formulations with more than 20% cassava flour and 10% soy flour were the least accepted in all sensory attributes investigated. It was therefore concluded that, for production of acceptable pasta products, the proportion of wheat flour in the formulation should not be below 80%. Further research is required to establish other factors, which could enhance acceptability of cassava- and soy-based pasta.

Genotype by environment interaction (GXE) for native cassava (*Manihot esculenta* Crantz) starch quality and its use in the commercial sector

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Abstract. Cassava (*Manihot esculenta* Crantz) is the second most important staple food crop in Sub-Saharan Africa providing an average of 285 calories per person per day. Cassava is an important food and cash crop, and it is increasingly becoming important industrial crop in Malawi. Various cassava intermediate products are used but industries hesitate to use cassava starch because powder sold by some suppliers in the name of cassava starch failed. This study therefore was initiated to look into native cassava starch qualities from different Malawi cassava genotypes, determine the appropriate stability parameter to deal with genotype by environment interaction (GxE) for starch quality traits, and also find out the possibility of use of cassava starch by the main industries in Malawi. Trials were conducted in Malawi in 2000/01 season. Apart from starch quality parameters, root dry matter and starch extraction evaluation were also included. Various stability measures were used to deal with the problem of genotype by environment interaction. Feasibility of use of cassava starch in Malawian industries was also conducted. The results show that all the cassava genotypes produced starch with no protein just like the one used in the pharmaceutical industry. The moisture and ash content were much lower than the recommended allowable maximum. The pH for cassava starch was within the recommended range. Additive main effects and multiplicative interaction (AMMI) was strongly correlated with other stability parameters like Wiercovalence and stability variance–no covariate. AMMI is therefore recommended for use in the stability analysis of starch quality parameters since it provides additional information on appropriate environments for unstable genotypes. This study suggests that genotype has a greater influence on root dry matter than the environment. This study showed that native cassava starch can be used in the pharmaceutical, battery and packaging material making and textile industries in Malawi, however strict quality control for cassava starch is required.

Evaluation of orange-fleshed sweetpotatoes varieties for resistance to sweetpotato virus disease

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Abstract. Use of orange-fleshed sweet potatoes (OFSP) rich in β -carotene, a precursor for vitamin A in the body, is being promoted as a food based approach to combat vitamin A deficiency in diets among vulnerable communities in Uganda. A number of OFSP varieties have been identified and tested. However, sweetpotato virus disease (SPVD) is a major production constraint in Uganda and most of the introduced OFSP materials have succumbed to the viral damage. It is important that before the OFSP are passed to the farmers they are evaluated for desired attributes. Thus experiments were conducted to evaluate different promising OFSP varieties in Uganda. These included SPK004, Zapallo, Naspot5, Ejumula, and Kala. New kawogo served as a SPVD-resistant, the control. The trial was laid out in a randomized complete

block design with varieties as treatments replicated four times. Mean number of plants with SPVD symptoms varied among varieties with New Kawogo being least affected. Total fresh weight, marketable weight and mean number of storage roots per plant varied significantly among varieties. The local cultivar Ejumula had a high yield but also had a high incidence of SPVD. Kala and SPK004 suffered the highest weevil damage in the first rains. There was non-significant negative correlation ($r = -0.23$, $P = 0.65$; $r = -0.16$, $P = 0.17$) between yield and cumulative SPVD incidence in both seasons. Susceptible varieties still yielded highest and are capable of yielding higher if SPVD is checked using cultural control methods such as roguing, planting clean vines and planting new fields at a distance (at least 100m).