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LONG-TERM PERFORMANCE OF AN IMPROVED CASSAVA CULTIVAR UNDER ANNUAL ALTERNATE FALLOW IN SOUTH-WESTERN NIGERIA

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Abstract

In sub-Saharan Africa, population and market pressures on the land are intensifying. Soil productivity is declining as fallow periods are shortening. Resource-poor farmers need alternative but affordable cropping systems if they are to raise and sustain crop productivity to feed growing populations. This study demonstrates that a practical cassava-based cropping system, suitable for these farmers, can achieve this aim. Cassava is becoming increasingly important in Africa because of its capacity to efficiently produce low-cost calories under marginal soil conditions. We grew an improved, high-yielding, pest-resistant, cassava cultivar (TMS 30572) in annual rotation with Mucuna mulch or weed fallow. This cropping system sustained productivity at about 20 t/ha rate that compared favourably with that of the local improved cv. 60506 (about 11 t/ha). This cultivar was grown on the same land for more than 12 consecutive years without fertilizer. When grown on Alfisols with high K reserve and initially high P level, Mucuna mulch can contribute to N nutrition. Retention of Mucuna mulch and crop residue contributes to nutritional recycling and crop yield sustainability.

Introduction

Cassava is a staple food crop in tropical Africa, even though it has been introduced relatively recently to some parts. It is widely cultivated by resource-poor farmers because of the crop's ability to produce low-cost, high-calorie food the year round, even when grown on low-fertility soils and marginal lands. It can also adapt to short fallow periods, improved crop rotations, and mixed cropping systems (Hahn 1989; Morgan 1959; Nweke 1992). Although it is mostly consumed for its starchy roots, its leaves which are rich in protein are also consumed, to varying degrees, as a green vegetable in many cassava-growing countries in Africa.

Cassava plays a major role in efforts to alleviate food crises in areas with marginal

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soils and erratic rainfall, so characteristic of Africa. Compounding the food crises are the low use of inputs and poor land and water management (Hahn and Keyser 1985; Hahn et al. 1987).

Profits from growing cassava are usually insufficient for buying fertilizers. Moreover, in the humid zones of Nigeria, the plant rarely responds to inorganic fertilizers particularly N and P as well as do other food crops (Kang and Okeke 1984; Kang et al. 1980, 1982).

Traditional farmers in West Africa use the bush fallow, slash-and-burn system for cultivating cassava. This system involves a sequence of several cropping cycles, followed by fallowing that allows the land to return to its natural vegetation. Soil fertility exhausted by cropping is thus restored. Where population pressure is low, this cropping system is relatively stable, characterized by short cropping cycles and long fallow periods. But where population growth is rapid, for various socio-economic reasons, fallow periods are shortened and crop productivity declines.

Thus, if productivity is to be increased and sustained, even with shortened fallow periods, an alternative to traditional cropping systems must be developed that is suitable for resource-poor farmers (Wilson and Lal 1986).

One way of improving the fallow system is to use a leguminous cover crop such as Mucuna (*Mucuna pruriens* var. *utilis* (Wall. ex Wight) Bak. ex Burck). The advantages of Mucuna are (1) it grows fast and provides quick surface soil coverage, (2) the residue forms a fairly uniform live mulch that suppresses weeds, (3) it dies naturally during the tropical dry season and the residue is light enough for land preparation in the following year, (4) it can minimize erosion, (5) it can maintain soil organic matter, (6) it reduces soil temperature, improves soil moisture retention, and promotes crop root growth and development (Lal 1987; Wilson and Lal 1986), and (7) it depresses populations of root-knot nematodes, which can reduce cassava yields by as much as 87% (Caveness 1992).

High-yielding improved cassava cultivars are available to many farmers in Nigeria (Nweke et al. 1993). Lal (1987) asked whether the high yield potentials of such improved cultivars can be sustained with appropriate methods of soil management, including a fallow system. This study assesses the feasibility of long-term sustenance of the soil, using improved cultivars in rotation with Mucuna fallow and no fertilizer.

Materials and Methods

Field experiments had been carried out annually, without fertilizer, from 1973 to 1992, to evaluate the performance of cassava breeding clones. The site was on 27.1 ha of a farm block at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. IITA is situated at 7°30´ N, 3°54´ E, with an altitude of 210 m, in the humid forest of a savannah transition zone. Annual rainfall is 1270 mm, with a unimodal distribution. The main rainy season is from April through November, and the main dry season from December through March. The mean annual temperature is 26.3 °C, and daily solar radiation is 405 cal/cm^2. The soil at the experimental site is an Alfisol (oxic Paleustalf), with sandy loam texture (Table 1).

The secondary forest at IITA was cleared manually between 1969 and 1974 to make the six main experimental farm blocks, each 200 ha. The experimental site used for this study (carried out between 1980 and 1992) was cleared in 1972 and contoured according to the slopes of the land (3%) in 1974. The experimental farm blocks were ploughed to a 25-cm depth, using tractors, and cultivated with various crops, including maize, cowpeas, rice, cassava, sweet potatoes, and/or yams, in rotation every year from 1970 to 1979. Cassava, sweet potatoes, and yams were planted on ridges spaced 1 m apart. In 1980, the farm blocks were rearranged as five blocks, each permanently assigned to a specific crop.

Before the rearrangement, cassava breeding trials had been carried out yearly across IITA's experiment farm blocks in a randomized complete block design with four replications, evaluating 12 to 25 clones per year, including two improved standard cultivars (IITA's TMS 30572 and the local 60444 or 60506). TMS 30572, released as ‘NC Idi-ose’, has been widely grown in Nigeria since the early 1980s; 60444 and 60506 are sister lines released in the early 1960s. Yield trials for cassava as a sole crop were conducted in rotation with maize, cowpeas, and sweet potatoes from 1973 to 1979.

From 1980 onwards, yield trials were carried out primarily for cassava as a sole crop in annual rotation with Mucuna or with weed fallow on one farm block known as ‘BS’, comprising 27.1 ha. Three to six such yield trials were conducted yearly from 1980 to 1992. Each plot had 40 plants (1 m apart) on four 10-m long ridges, but only 20 plants from the two central rows were harvested for yield estimations. The breeding clones were planted at the onset of the rainy season (April-June) and harvested the following year.

In the second year, the land was fallowed with Mucuna (30 kg seed/ha, spaced at 75 x 75 cm) or left fallow with volunteer weeds if it were not possible to sow Mucuna. This allowed the land to rest for one year before cassava was planted again in the third year. Half of the land was therefore always at rest, whether under Mucuna or weed fallow. This cropping system was repeated for 12 consecutive years, from 1980 to 1992.

The data on the average yields of the 3-6 trials for each year (1980 to 1992) were used in this study. Only the yield data of the two standard cultivars TMS 30572 and 60444 (or 60506) were considered. The local improved standard cv. 60444 was used from 1973 to 1979 and replaced with cv. 60506 in 1980 as the latter performed better.

Soil data for 1973 were obtained from Moorman et al. (1975). Surface soil samples were taken from the experimental site in 1983, 1990, and 1993, and analysed for mechanical and various chemical properties, according to IITA's standard methods (IITA 1982).

Results and Discussion

Cassava Root Yields

Average root yields of both TMS 30572 and the local cultivar (60444 or 60506) from 1973 to 1992 were 26.7 t/ha and 13.5 t/ha, respectively. TMS 30572 consistently outperformed the local cultivar. Root yields decreased sharply in the first 8 years, but levelled off in 1980, onwards. This sharp decline in yield corresponds to rapid decreases in soil nutrient status, a result of cropping not only cassava but also other crops when they were grown across the farm blocks during the period. From 1980 onwards, when the cultivation of cassava was alternated with Mucuna or weed fallow on the same field without fertilizer, both cultivars showed sustained production at 19.5 t/ha for TMS 30572 and at 11.2 t/ha for the local cultivar. The Institute's cultivar performed 74% better than the local one.

The sustainability of cassava production under this cropping system will be examined below from four angles: soil, alternate fallow with Mucuna or weeds, nutrition of cassava plants, and improved cassava genotype.

Soil Properties and Fertilizer Response

Some properties of the surface soils in 1973, 1983, 1990, and 1993 are presented in Table 1. Cassava monoculture in association with Mucuna did not alter soil pH or the levels of N, P, K, Na, Mn, Al, organic C, or total acidity. However, Ca, Mg, CEC levels, and extractable P were significantly lowered. Sand content of soil increased, while silt and clay contents decreased significantly. Such changes in the soil occurred mostly in the first decade (1973-1983), following clearing in 1972 and cropping with various crops, but changed very little thereafter.

Interestingly, results show that, on this high-base Alfisol derived from basement complex rocks (Moorman et al. 1975), cassava monoculture without soil amendments (except for the annual rotation with Mucuna or weed fallow) little affected soil properties, and cassava yield was sustained.

Odurukwe and Oji (1984) studied the effects of fertilizers and manure on cassava yields in eastern Nigeria (high rainfall area) from 1974 to 1978. The experimental site had lain fallow for several years before being cleared of grass regrowth. The authors reported that the initial yield of 19.7 t/ha declined to 13.0 t/ha (33.8%) in 1975; 10.7 t/ha (45.8%) in 1976; and 10.3 t/ha (49.1%) in 1978. On this site's soils, yields could not be sustained in continuous cropping, even with yearly dressings of manure (20 t/ha) or fertilizer (44 kg N, 34 kg P, 90 K kg/ha). This yield decline, despite the application of manure and fertilizers, was attributed to micronutrient deficiency.

Kang and Okeke (1984) also reported a large root yield response to N and K application, following three consecutive croppings on an Alfisol (oxic Paleustalf) derived from sandy parent material in the forest zone of Nigeria. Soil K levels decreased from 0.15 to 0.10 mg K/100 g in the third cropping year.

Annual Alternate Fallow with Mucuna or Weeds

Mucuna fallowing, which suppressed root-knot nematodes and improved soil fertility, also had favourable effects on sustainability of cassava yield. Estimation of Mucuna dry biomass yield in 1990 showed a DM yield of 2.6 t/ha. This material contains about 94.6 kg N, 3.1 kg P, and 49.0 kg K per hectare. The high N yield of Mucuna mulch is partly a result of biological N fixation. Inclusion of Mucuna in the rotation system can therefore contribute to N nutrition of the cassava crop.

For good Mucuna growth, an adequate supply of P is needed, which was apparently provided by the high residual P levels of the site. Although Mucuna also contributes to recycling of other nutrients, its contribution is rather small. During the fallow period, the pathogens of soil-borne diseases of cassava must also have been reduced.

The weeds most commonly occurring in the farm block during the cropping season were *Euphorbia heterophylla* (Euphorbiaceae), *Talinum triangulare* (Portulacaceae), *Tridax procumbens* (Asteraceae), *Spigelia anthelmia* (Loganiaceae), *Euphorbia hirta* (Euphorbiaceae), *Digitaria horizontalis* (Poaceae), *Cyperus sphacelatus* (Cyperaceae), and *Cyperus tuberosus* (Cyperaceae). We did not collect data on the DM produced yearly by the weeds occurring at the experiment site, but we believe it to be substantial in the light of Akobundu's report (1992): 2.9 t/ha of dried weeds for the rainy season. Weeds may thus be another important source of organic matter, playing a role similar to that of the cover crops in sustaining soil fertility and productivity, as well as in protecting soil from erosion during the fallow period.

Nutrient Recycling, Cassava Crop

Cassava is a long-cycle crop that can be left unharvested in the field for 2-3 years until required. Following establishment, plants grow continuously during the rainy season. Plant growth and leaf production slow down at the end of the rainy season and stop during the peak of the dry season. Growth resumes with the onset of the rainy season (Conner et al. 1981).

During growth, older leaves are shed. The average life span of cassava leaves is estimated to be about 40 days (M. Porto, 1993, personal communication). Leaf litter covers the ground as mulch, reducing surface soil temperature and conserving soil moisture, particularly during short dry spells. Leaf litter can be readily decomposed by microbial and faunal activities in 2-3 months, thereby assisting in nutrient recycling. As cassava is a deep-rooting crop (2.3-2.6 m) (Conner et al. 1981; Lal and Maurya 1982), it can take up nutrients from lower soil depths, thereby contributing more to nutrient recycling than do shallow-rooting food crops.

The N, P, and K nutrient contents of a 12-month-old cassava crop with a root yield of 20 t/ha are estimated as 157 kg N, 30 kg P, and 229 kg K per hectare (Obigbesan 1977). The amount of N, P, and K removed by a crop with a root yield of 15 t/ha is estimated to be 30 kg N, 8 kg P, and 50 kg K per hectare (EMBRAPA-CNPMF 1980). The dry leaf litter of cv. TMS 30572, which can be as much as 4 t/ha per year, contains about 147.5 kg N, 10.8 kg P, and 60.5 kg K per hectare (D. Osiru, 1990, personal communication). Leaving the stems in the field after harvest, as practised by traditional farmers in tropical Africa, will also add additional nutrients to the soil. Estimates reported by EMBRAPA-CNPMF (1980) showed that for a root yield of 20 t/ha, the corresponding stems contain 12 kg N, 5 kg P, and 15 kg K per hectare.

Thus, although the amount of nutrients recycled by leaf and stem litter can easily meet the amount of N and P removed with the crop harvest, and also meets most the crop's N and P needs, it does not fulfil all requirements.

The soil at our experimental site has a high level of exchangeable K. Despite continuous cropping, the soil can still meet crop requirements (Table 1). Kang and Balasubramanian (1990) reported that on similar soil, it took 8 years of intensive maize cropping before a K response was observed. The high levels of extractable soil P at the experimental site may have resulted from P applied to crops grown before 1980. Kang and Osiname (1979) showed a high residual effect of applied P on similar soils. As cassava is known to have a low P requirement (Kang et al. 1980), the residual P in the soil appears to be adequate to meet the crop's requirements for several years yet, even without P application.

Leihner and López (1988) reported that 9 years of continuous cultivation of cassava without fertilizer in Colombia depressed root yield to about one-third of that of the first cassava crop in the field, even though the nutrient elements in the soil were above the critical levels for cassava. The average yield of a cassava cultivar grown on a soil with a low plant-nutrient content for 10 years in Indonesia was 5.9 t/ha, showing very little yield decline over the years when grown continuously without fertilizer versus 8.3 t/ha when fertilized (Kang 1974).

These reports also indicate that cassava is able to sustain soil fertility and productivity in the tropics for long periods, contrary to the common belief that this crop depletes soils the most. As cassava is normally grown last in cropping sequences before fallow, it is often considered responsible for soil degradation (Hahn et al. 1987). In fact, the soil has been depleted by crops grown before cassava (Kang and Okeke 1984).

Improved Cultivar TMS 30572

In recent random surveys, the Collaborative Study of Cassava in Africa (COSCA) reported that, in Nigeria, those IITA-improved cultivars (primarily TMS 30572) that are resistant to the African cassava mosaic disease (ACMD) are extensively adopted and grown by farmers on 60% of land planted to cassava in the humid zones, 35% in the subhumid zones, and 40% in the semi-arid zones (Nweke et al. 1993). Farmers appreciate the cultivar's high and sustainable productivity under the prevailing ecological, agronomic, and socio-economic conditions. Nigeria is reported to be the largest cassava producer in the world, probably because of the adoption of this cultivar (FAO 1990).

Conclusions

Annual rotation of cassava with Mucuna or weed fallow sustained the productivity of cassava without fertilizer on fragile tropical soils for 12 years. Yields were about 20 t/ha for the IITA-improved cv. TMS 30572 and 11 t/ha for the local improved cv. 60506. Under such a cropping system, the total amount of nutrients contributed by Mucuna or weeds, as well as by cassava leaf-and-stem litter, seems to satisfy the nutrient requirements for sustainable cassava production. In addition, fallowing for one year can also improve soil productivity significantly by replenishing useful soil micro-organisms and reducing harmful pests, particularly root-knot nematodes.

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To save space, the following acronym is used:

IITA International Institute of Tropical Agriculture

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Table 1. The physico-chemical properties of the Egbeda series of soil (0-15 cm) in Block BS[a] at the International Institute of Tropical Agriculture, Ibadan, Nigeria, surveyed in 1973, 1983, 1990, and 1993.

Property	**Year of survey**			
	1973	**1983**	**1990**	**1993**
No.[b]	3	520	18	54
PH (H_20)	6.4	6.20 ± 0.02	5.80 ± 0.04	6.30 ± 0.04
Exchangeable cations (meq/100 g)				
Ca	4.63	3.61 ± 0.10	3.27 ± 0.25	2.65 ± 0.22
Mg	1.27	0.70 ± 0.02	0.77 ± 0.04	0.53 ± 0.03
K	0.23	0.28 ± 0.01	0.32 ± 0.02	0.20 ± 0.02
Na	0.07		0.26 ± 0.02	0.18 ± 0.02
Mn	0.10		0.20 ± 0.01	0.11 ± 0.11
Al	0.01		0.02 ± 0.01	0.00 ± 0.00
CEC (meq/100 g)	6.47		4.95 ± 0.31	3.86 ± 0.27
Organic C (%)	1.51	0.83 ± 0.01	0.75 ± 0.05	1.03 ± 0.06
Total N (%)	0.081	0.083 ± 0.001	0.106 ± 0.004	0.106 ± 0.004
Available P (ppm)	9.15	22.59 ± 1.40	9.82 ± 1.90	11.81 ± 1.97
Total acidity (meq/100 g)	0.16		0.14 ± 0.02	0.18 ± 0.01
Base saturation (%)	97.3		97.3	
C:N ratio	18.6	10.40	7.08	9.72
Mechanical analysis (%)				
Sand	60.8	80.67 ± 0.3	76.40 ± 1.0	84.90 ± 0.5
Silt	15.1	8.30 ± 0.1	9.20 ± 0.3	6.80 ± 0.3
Clay	23.9	11.10 ± 0.2	14.20 ± 1.0	8.30 ± 0.3

a. Secondary forest manually cleared in 1973 and cropped every other year with cassava for 12 consecutive years (1980-1992) without fertilizer, but rotated with Mucuna or weed fallow after harvest.

b. Number of soil samples taken from the field for analysis.

SOURCE: Moorman et al. 1975.