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EXPANDING THE GENETIC BASE OF CASSAVA IN AFRICA: PROGRESS AND PROSPECTS

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Introduction

Cassava (*Manihot esculenta*) is the fourth most important source of food energy in the tropics. In Africa, the crop's capacity to grow and yield well on low fertility soils and tolerate drought, and its low cost of production have provided economic incentives for farmers to replace other crops with cassava.

Unstable yields in cassava are a consequence of the complex of diseases and pests that attack the crop. Researchers in Africa have relatively limited diversity of source populations from which to select broad-based genotypes adapted to the various agro-ecologies and consumer requirements.

Success in a crop-breeding programme depends on understanding the germ plasm resources available. To this end, and to overcome pest constraints, building a broad genetic base for breeders to work with becomes extremely important.

Measures have been taken to explore the diverse genetic variability found in South America (the centre of origin and diversity of cassava) through collaborative cooperation of two international institutions with a mandate for cassava improvement: CIAT and the International Institute of Tropical Agriculture (IITA).

CIAT is caretaker of the world's largest collection of cassava germ plasm, maintained in Palmira, Colombia. The collection has been extensively evaluated under diverse edaphic, climatic, and pest conditions (CIAT 1985). It contains a wide range of diversity for nearly all traits, including morphological, agronomic, quality, and pest and disease resistance traits (Hershey 1985).

CIAT and IITA have been actively involved in a joint project with the objective of expanding the genetic base of cassava in Africa (Porto and Asiedu 1992; Porto et al. 1994).

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As part of the collaborative project, CIAT has been systematically involved in the introduction of Latin American germ plasm (through F_1 seeds) into Africa. The later development of that germ plasm depended largely on how these introduced materials overcame the biotic and abiotic stresses found on the continent.

Germ Plasm Introduction into Africa

The genetic base of cassava is being broadened through the introduction of progenies obtained from crosses between complementary genotypes (Porto and Asiedu 1992). Improved CIAT clones and Latin American landraces adapted to selected agro-ecologies and possessing several desirable traits are being used as parents for obtaining segregating populations. Also being used are 19 IITA elite clones as sources of genetic resistance to the African cassava mosaic virus (ACMV) in crosses made at CIAT. Seeds of F_1 progenies from controlled hybridization and open pollination are tested for the presence of all known viruses in Latin America and treated by thermotherapy and pesticides at CIAT before being introduced into Africa.

After the seeds undergo the required quarantine procedures at IITA and the Nigerian Plant Quarantine Service, they are planted in a screenhouse and then transplanted to the field in targeted agro-ecologies for evaluation.

About 300,000 botanical seeds, representing 1,600 families, were received at IITA between 1990 and 1994 (Table 1). In 1993, 10,000 seeds were received from the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, the Brazilian agricultural research agency), as part of a project for developing cassava germplasm for the semi-arid areas of Latin America and Africa and funded by the International Fund for Agricultural Development (IFAD).

Evaluation of Latin American Cassava Germ Plasm

Since the beginning of the collaborative project between CIAT and IITA, six evaluation sites, representing various agro-ecological zones (AEZs) of interest, have been used in Nigeria: Kano (semi-arid); Jos (mid-altitude); Ibadan (subhumid); Onne, substituted later by Warri (humid); and Zaria (northern Guinea savannah zone).

CIAT is responsible for the pre-breeding stage, that is, for the introduction, establishment, and field evaluation of F_1 progenies. IITA, in turn, is responsible for breeding, that is, clonal evaluation trials (CET), preliminary yield trials (PYT), advanced yield trials

(AYT), and uniform yield trials (UYT), including further population improvement (TRIP, 1993) (Table 1).

Evaluation for pests and diseases include African cassava mosaic disease (ACMD), cassava bacterial blight (CBB), cassava anthracnose disease (CAD), cassava mealy bug (CMB), and cassava green mite (CGM). The severity of damage by pests is rated on a scale of 1 to 5, where 1 = resistant or healthy plants and 5 = highly susceptible plants (Hahn and Ikotun 1989).

CAD is an important constraint in the humid and subhumid agro-ecologies, and the introduced germ plasm showed an intermediate reaction to the disease, similar to that observed for IITA clones. Latin American clones were not seriously affected by CMB (*Phenacoccus manihotis*) or by CGM (*Mononychellus tanajoa*) at any site.

ACMD had the most devastating effect on the introduced germ plasm in the humid and subhumid agro-ecologies (Table 2). In contrast, F_1 progenies evaluated in the mid-altitude and semi-arid areas did not suffer severe damage from ACMD because of low pressure from the virus and reduced vector activity in those ecosystems. At Ibadan and Onne, where ACMD pressure is high, the proportion of introduced seedlings and clones selected in the seedling nurseries and yield trials was very low. None of the F_1 progenies introduced in 1990 at Ibadan and Onne was advanced to the UYT stage because of susceptibility to ACMD. Some of the F_1 progenies, however, were used for crosses at IITA.

Two IITA elite clones are being used as check varieties at Ibadan. TMS 30001 (resistant to ACMV) did better than CIAT seedlings and TMS 91934 (susceptible to ACMV) was somewhat similar in performance to the introduced germ plasm (Table 2). The low pressure of ACMV in Kano made maintaining a range of introduced genetic variability possible for this agro-ecology. Evaluation for CGM showed that, on the average, the introduced germ plasm performed well when compared with TMS 91934, which is resistant, and with the susceptible TMS 30001.

CIAT has successfully bred for resistance against CBB in Latin America. Consequently, many introduced F_1 progenies were tolerant of this disease. CBB is more pronounced in humid and subhumid agro-ecologies, where rainfall is high, compared with semi-arid and mid-altitude areas. Overall reaction in introduced germ plasm was least at Kano, moderate at Jos, and severe at Ibadan and Onne in those plants that had not been eliminated by the disease in early stages of development. Cassava introduced from Latin America shows greater promise as sources of resistance to CBB than to ACMV. Few problems arise in selecting CBB-resistant genotypes and maintaining genetic variability in

IITA breeding trials. At harvest, morphological, agronomic, and quality traits are also evaluated.

Between 1990 and 1993, the CIAT/IITA collaboration transferred recombinant seed from 82% and 84% of the elite clones with high yield potential and high root dry matter content, respectively (Porto, 1993). Many of these genotypes were of the high branching type.

Most introductions have brown to dark brown roots, with white or cream-coloured root parenchyma and little or no pigmentation in the root cortex. Some genotypes had low root cyanide content and mealiness, but these characteristics are highly influenced by environment and time of harvest.

Challenges

The recently introduced Latin American cassava germ plasm also appears promising for the mid-altitude and semi-arid agro-ecologies and for the Guinea savannah. As a result, considerable genetic variability of Latin American cassava is being maintained at Jos, Kano, and Zaria in various stages of IITA's breeding programme (Porto 1993; TRIP 1993).

Latin American cassava with good plant vigour and high yield potential have been selected in Kano for semi-arid agro-ecologies. In 1994, again in Kano, 135 clones are being evaluated in field trials: CET (63 clones), PYT (31), ATY (25), and UYT (16). Genotypes are primarily selected for drought tolerance, which is essential for adaptability to semi-arid ecologies. Current efforts on Latin American germ plasm introductions, especially from North-East Brazil, need to be intensified to provide better chances of selecting for drought tolerance, high vigour, high yield potential, and quality traits.

The incidence of ACMD at Jos is very low, thus permitting a broader range of genotypes from Latin America to survive. The only disease of importance in the mid-altitude site appears to be CBB, to which CIAT introductions have a considerable resistance. Although some plants have adequate height and vigour, most of the F_1 progenies are shorter than 1.5 m because of the suboptimal temperatures (10-15 ^oC) that occur during part of the growth cycle in this agro-ecology.

Genotypes that tolerate low temperatures are highly desirable for mid-altitude savannah areas. Given the lower rainfall at Jos (compared with the humid and subhumid agro-ecologies), genotypes should be selected for water-use efficiency and rapid vegetative growth, combined with good bulking rates.

Cloudiness during the rainy season in Jos means that solar radiation is low: at Vom near Jos, daily radiation is 14 mJ/m^2, compared with 18 mJ/m^2 during the dry season. Selected genotypes must therefore have good photosynthetic rates at low radiation levels. Genotypes from Latin American highlands would effectively complement IITA research efforts for this agro-ecology.

The acute susceptibility of introduced germ plasm to ACMV in humid and subhumid agro-ecologies have greatly limited the advancement of Latin American germ plasm to IITA yield trials, despite having other desirable traits. Some F_1 progenies, derived from crosses between Latin American and African genotypes through controlled hybridization, do tolerate the disease to some degree. Some resistant genotypes also came from open-pollinated seeds, using Latin American clones as female parents.

Crosses between Latin American elite clones and ACMV-resistant IITA elite clones have always resisted ACMV better than have progenies of pure Latin American origin (Table 3). The proportion of CIAT x IITA crosses at CIAT (Colombia) has significantly increased since 1990, being a strategy to develop Latin American germ plasm with greater adaptation to the production constraints prevalent in Africa.

More intense efforts are needed to ensure that more introductions to the mid-altitude and semi-arid ecologies have ACMV-resistant clones as parents. This would help limit the diffusion and incidence of the disease.

The use of molecular markers in mapping genes for ACMV resistance would be most useful in the introgression of ACMV resistance in Latin American cassava germ plasm. Pre-breeding for resistance to ACMV could then be conducted in Latin America in the absence of the disease by ensuring that populations have high frequencies of closely linked DNA molecular markers.

Cassava is an important food crop in Africa; its average fresh root yield of 11.9 t/ha (Nweke et al. 1994) still need to be improved, together with root quality, through the concerted efforts of the CIAT/IITA collaboration. As consumption of cassava leaves as a vegetable increases in Central and West Africa, F_1 progenies should also be selected for good canopy development.

Although, traditional cassava processing in Africa effectively reduces cyanide levels in roots, genotypes with low cyanogenic potential should be selected for those areas where cassava is eaten after boiling only or raw. The Collaborative Study of Cassava in Africa (COSCA) has shown that 30% of cassava produced in Africa is not adequately processed before eating. Of, primary importance to cassava research for Africa, therefore, is the selection of cassava genotypes that have low cyanogenic potential and 'good mealiness' (i.e., easy to pound).

Cassava with yellow pulp (i.e., high carotene content) is also highly desired and can contribute to enhancing nutritional status in Africa. Some introduced Latin American germ plasm has already been characterized for this trait. Progenies from genotypes representing 48% of CIAT elite germ plasm with yellow flesh have been transferred to IITA between 1990 and 1993 (Porto 1993). Other quality characteristics for processing and taste will also need to be considered.

Conclusions

CIAT and IITA have been collaborating for several years to improve the flow of germ plasm to Africa and facilitate its use in national breeding programmes to broaden the genetic base of African cassava. African farmers benefit from the introduction of F_1 progenies from South America and their subsequent use in cassava crop improvement in terms of food security, self-sufficiency, and increased income. To realize the full potential of Latin American germ plasm, introduced progenies should be further improved for resistance to ACMV, a disease that is probably absent from the crop's centre of origin.

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Table 1. Number of Latin American genotypes at various stages of evaluation at Ibadan, Onne, and Warri in Nigeria, 1990-1994.

Site, Trial	1990	1991	1992	1993	1994
Ibadan					
Seedling	5,400	5,300	3,514	3,800	572
Clonal evaluation		538	253	117	
Preliminary Yield Trial			9	10	26
Advanced Yield Trial				2	2
Onne					
Seedling	3,699	4,174	668		
Clonal evaluation		311	61		
Preliminary Yield Trial			17		
Warri					
Clonal evaluation				30	
Preliminary Yield Trial				8	4
Advanced Yield Trial					1
Kano					
Seedling	3,288	11,555	2,580	4,325	3,142
Clonal evaluation		474	194	152	402
Preliminary yield trial			38	58	63
Advanced yield trial				21	31
Uniform yield trial					16
Zaria					
Seedling		474	233	147	235
Clonal evaluation			53	22	12
Preliminary yield trial				11	10
Advanced yield trial					5
Jos					
Seedling nursery		13,168	2,564	2,362	5,160
Clonal evaluation			265	140	132
Preliminary yield trial				34	34

Table 2. Evaluation for reaction to two diseases and a pest in introduced germ plasm and IITA elite clones at Ibadan, Nigeria, 1991-1994.[a]

Period	Introduced recombinant progrenies			IITA elite clones					
				TMS 91934			TMS 30001		
	ACMD	CBB	CGM	ACMD	CBB	CGM	ACMD	CBB	CGM
1991/92	3.42	2.57	2.28	2.58	2.20	2.47	1.82	2.00	3.04
1992/93	3.60	2.40	2.77	2.83	1.89	2.72	1.56	1.85	3.23
1993/94	3.27	2.23	2.25	2.73	1.71	2.46	1.39	1.67	3.17

a. ACMD = African cassava mosaic disease.
CBB = cassava bacterial blight.
CGM = cassava green spider mite.
Disease reaction evaluated on a scale of 1 to 5, where 1 = resistant, healthy plants, and 5 = highly susceptible plants.
IITA = International Institute of Tropical Agriculture.

Table 3. Monthly evaluations of the incidence[a] of the African cassava mosaic disease in cassava seedlings of different genetic backgrounds, Ibadan, Nigeria. Values are averaged for 1991-1994.

Month	CIAT/IITA controlled hybridization	100% Latin American controlled hybridization	Open- pollination
June	1.7	1.8	1.9
July	3.0	3.2	3.7
August	3.3	3.5	3.8
September	3.3	3.7	4.1
October	3.1	3.6	4.1
November	3.1	3.7	3.9
December	2.6	3.0	3.4
January	3.1	3.2	3.3
February	2.9	3.1	3.2
March	2.8	3.0	3.3
April	3.0	3.0	3.4

a. Incidence is rated on a scale of 1 to 5, where 1 = no symptoms and 5 = severely affected.