

BREEDING CASSAVA FOR MULTIPLE PEST RESISTANCE IN AFRICA

N.M. MAHUNGU, A.G.O. DIXON¹ and J.M. KUMBIRA
FAO/UNDP Cassava Project, Lunyangwa Research Station;
P.O. Box 59, Mzuzu, Malawi.

¹International Institute of Tropical Agriculture (IITA);
P.M.B. 5320, Ibadan, Nigeria.

ABSTRACT

The major constraints to stable production of cassava in Africa are diseases, insects, mites, weeds, soil and agronomic limitations and socio-economic factors. Of the economic diseases, African cassava mosaic, bacterial blight, and anthracnose are the most important. The green spider mite and cassava mealybug are by far the most economically important arthropod pests. The long growing period and diverse agroecologies in which cassava cultivars are grown expose them to one or more of these problems and the losses can be devastating. Multiple pest resistance helps to ensure stability of crop performance. Research experience, progress and prospects in breeding cassava for resistance to the pests of greatest economic importance in Africa are presented.

Key Words: Cassava, diseases, improvement, pests

RÉSUMÉ

Les principales contraintes à une production stable de manioc en Afrique sont représentées par des maladies, des insectes, des acariens, des mauvaises herbes ainsi que par des contraintes agronomiques et des facteurs socio économiques. La mosaïque africaine du manioc, la bactériose vasculaire, et l'anthracnose sont les plus importantes des maladies d'intérêt économique. L'acarien vert et la cochenille farineuse sont les arthropodes les plus importants au plan économique. La croissance lente du manioc et la diversité des situations agroécologiques de la culture de ses cultivars l'expose à un ou plusieurs de ces ravageurs, qui peuvent alors être dévastateurs. Une résistance multiple aux ravageurs permet d'assurer la stabilité de la production. Les acquis de la recherche, les travaux en cours et les perspectives, dans le domaine de la sélection du manioc pour une résistance aux ravageurs de grande importance économique en Afrique, sont présentés.

Mots Clés: Manioc, maladies, amélioration, ravageurs

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the most important crops in sub-Saharan Africa and accounts for approximately one-third of the total staple food production of the continent. The crop is grown almost exclusively as food in 39 countries stretching in a wide belt from the island of Madagascar in the south-east to Senegal and the

Cape Verde Islands in the north-west (Hahn and Keyser, 1985). Production is in areas where the rainfall exceeds 600 mm over a period of at least 2 to 3 months and altitudes range from sea level to 1800 m. Cassava storage roots form the basic carbohydrate component of the diet and the leaves are consumed as a preferred green vegetable in many parts of Africa, providing protein, minerals and vitamins (Hahn, 1989; Dahniya, 1994).

The average root yield of cassava in Africa is below the world average because of the inherently low yielding ability of many of the local cultivars grown, together with losses due to diseases, insects, mites, weeds, soil and agronomic constraints and socio-economic factors (Dixon *et al.*, 1992).

Cassava improvement programmes seek to widen and improve the genetic base of cassava in Africa and maintain its adaptability through population improvement targeted to specific agro-ecologies. In so doing, elite segregating cassava source populations for target environments are generated that possess various degrees and types of resistance to major pests (Dixon *et al.*, 1992). This is crucial because the long growing period and diverse agro-ecologies in which cassava is cultivated expose it to many biotic stresses, some of which are devastating, especially when acting synergistically with other stresses. Diseases tend to be most conspicuous during the rainy season, whereas arthropod pests are most prevalent during the dry season. The two groups of problems can cause serious losses. However, a solution to any one disease or arthropod pest problem does not necessarily lead to increased production of cassava. Solutions should be sought simultaneously for all the major constraints including diseases, insects and mites.

MAJOR DISEASES AND ARTHROPOD PESTS OF CASSAVA

The most important of the diseases affecting the leaves of cassava in Africa are African cassava mosaic virus disease (ACMVD), cassava bacterial blight (CBB), cassava angular leaf spot and cercospora leaf spot. Stem diseases include anthracnose (CAD). Root diseases comprise soft rot and dry rot, sclerotium rot, as well as damage due to nematodes. Additional information on the fungal diseases and nematodes of cassava are given by Coyne (1994) and Makambila (1994). However, ACMVD, CBB and CAD are by far the three most important diseases of cassava in sub-Saharan Africa (Hahn and Williams, 1973; Bock and Guthrie, 1976; Boher *et al.*, 1978; Daniel *et al.*, 1978; Lozano, 1978; Makambila, 1978; Mostade and Butare, 1978; Hahn *et al.*, 1989; Geddes, 1990).

There are also several important arthropod pests

of cassava namely, cassava green mite (CGM) (*Mononychellus tanajoa* Bondar), cassava mealybug (CM) (*Phenacoccus manihoti* Matile-Ferrero), variegated and elegant grasshoppers, cassava scale insects, coreid bugs, whiteflies (*Bemisia* spp.) and red spider mites (*Oligonychus* and *Tetranychus* spp.). Cassava green mite and CM are the most economically important of these pests (Hahn *et al.*, 1989; Geddes, 1990; Yaninek *et al.*, 1990) and are described in detail elsewhere in this volume (Neuenschwander, 1994; Yaninek *et al.*, 1994).

BREEDING OBJECTIVES

The objectives of cassava improvement programmes in Africa include: (i) high yield in terms of dry matter per unit area per unit time; (ii) resistance to the major diseases present in the target ecologies (particularly ACMVD, CBB, and CAD); (iii) resistance to the major arthropod pests in target ecologies (particularly CGM and CM); (iv) improved root quality in terms of local consumption practices (e.g. low cyanide, mealiness, carotene content); (v) improved plant architecture in terms of canopy and roots; (vi) adaptability and sustainability (selection under low input systems - in the early growth stages, and fertilizer use at the advanced stages); (vii) adaptability to varied environments and cropping systems.

To attain these objectives requires the expertise of many scientific disciplines and involves the close cooperation of scientists in plant breeding, plant pathology, entomology, virology, agronomy, socio-economics, biochemistry, food technology, agricultural engineering, plant physiology and tissue culture.

BREEDING STRATEGY

Source populations. The first stages in any breeding programme involve an assessment of farmers and end-users needs followed by the acquisition of source populations. This necessitates germplasm collection, evaluation and selection. The basic materials for cassava source populations are local and introduced germplasm. The selected clones or families from the initial evaluations are hybridised to form base

populations for target agroecologies and for selection for various desirable characteristics.

Selection of parental materials. The proper choice of parental materials and/or populations from which to develop improved varieties is very important for efficient genetic progress. The first requirement for selecting parents is an assessment of the genetic variability in the germplasm for important agronomic traits as well as resistance to target pests. Selected parents are planted in a crossing block for deriving full-sib and /or half-sib families [open-pollinated (OP) seeds].

The evaluation of the progenies for resistance to a given pest, in addition to other important attributes, helps in determining the breeding values of the parents of crosses (families). Table 1 shows the frequencies of selected resistant seedlings for ACMD and CGM resistance from OP seedlings of eight parents in Malawi in 1992. The local varieties, Nausi and Kamphunobi and the improved cultivar TMS 91934 were found to be parents with good breeding values. Some of their progenies showed good resistance to both ACMD and CGM. It is recommended therefore that crosses should be made between those parents with higher breeding values to increase the probability of success in breeding for resistance to ACMD and CGM.

Site selection. The selection site should as far as possible be subject to many of the important stress factors for the particular target region. This will facilitate the selection of materials that are of use

in other similar regions. Clones selected in high stress situations are likely have adequate resistance or tolerance over a wide range of conditions including non-stress environments. By contrast, selection under non-stress situations may result in clones with inadequate resistance or tolerance when stressed.

The number of evaluation sites necessary in a screening programme depends upon the diversity of the target area, the occurrence of pest "hot spots" and the researcher's ability to operate efficiently in those sites.

From records of the severity of CBB, CGM and ACMD on the same genotypes evaluated over a wide range of environments in Malawi (Fig. 1), hot spots were identified for screening for each of the above pests. Cassava bacterial blight was prominent at the Bvumbwe and Meru sites, CGM at Chitala, Mkondezi and Makoka and ACMD at Baka and Mkondezi. These sites were chosen for screening against the whole range of pests.

Establishment of screening trials. The evaluation of genotypes is done in the breeding trials following the selection scheme of Hahn *et al.* (1979). Ideally the breeding plots should be isolated from other field trials (agronomic, multiplication, etc.) to avoid spread of pests to these trials. The screening activities described below are undertaken jointly with crop protection and crop production specialists. The seedling nursery (first selection stage) is established in an area of high pest pressure. Spreader rows planted with susceptible genotypes are usually

TABLE 1. Frequencies of seedlings selected as resistant to African cassava mosaic disease (ACMD) and cassava green mite (CGM) from seedlings of eight parents at Chitali, Malawi in 1992

Parent	Frequency (%) of resistant seedlings			
	Number of seedlings planted	ACMD alone	CGM alone	ACMD & CGM
Mbundumali	700	3.6	5.7	1.7
TMS 91934	1200	10.8	15.4	7.9
TMS 60142	1350	3.0	1.1	0.0
TMS 4(2)1425	900	7.7	5.0	2.4
Kamphunobi	1150	8.1	12.2	6.4
Gomani	660	3.0	1.1	0.0
Kolobeka	60	1.7	0.0	0.0
Nausi	105	19.1	30.5	10.5

incorporated in each trial. After the pre-selection of seedlings under natural pest occurrence, artificial inoculation for CBB using the stem puncture method and infestation for CGM with infested leaves are done on each seedling. This increases the pest pressure on previously selected seedlings which may have escaped earlier if low pressure had been encountered. Towards the end of the rainy season, each individual seedling should be de-topped to induce expression of ACMD symptoms in the young sprouting leaves. These fresh shoots and leaves will also facilitate screening for CGM and CM which are predominantly dry season pests and prefer young foliage. No roguing of undesirable or discarded seedlings is advocated to help maintain the pest pressure. Tagging of selected seedlings with ribbons or tags is appropriate.

The genotypes established in the clonal evaluation (second selection stage) are evaluated and scored for their resistance to the major pests and diseases. Cassava green mite and CBB are again inoculated artificially 3-5 months after planting. No de-topping is advocated as some of the main agronomic traits are recorded at this stage. Screening for resistance from the preliminary yield trials onwards can be done

simultaneously in the field and in the screenhouse and/or glasshouse as the number of genotypes is reduced. Cassava bacterial blight evaluations in the glasshouse are more efficient as some of the factors such as temperature and humidity can be maintained at optimum levels for development of the disease and symptom expression.

Pest assessment. Most of the important diseases and arthropods are evaluated for damage symptoms on a subjective scale of 1-5 (1=no damage, 5=severe damage) (Anonymous, 1990). However, the expression of symptoms in the field may differ from plant to plant of the same breeding clone which is supposed to be genetically identical. Thus average score alone based on severity of symptoms may be a misleading basis for selection. It is desirable to score the most severely affected plants of the clone. Alternatively, both incidence of the pest (proportion of affected plants) in the clone and the severity of the most affected plants can be scored. Symptom evaluations in Malawi as reported in Table 2 showed that individual plants of clone MK 90/1160 had a score of 3.0 in the 1990/91 growing season, though other plants were uninfected and the overall mean score for all plants was only 1.3. The score of 3.0 revealed at

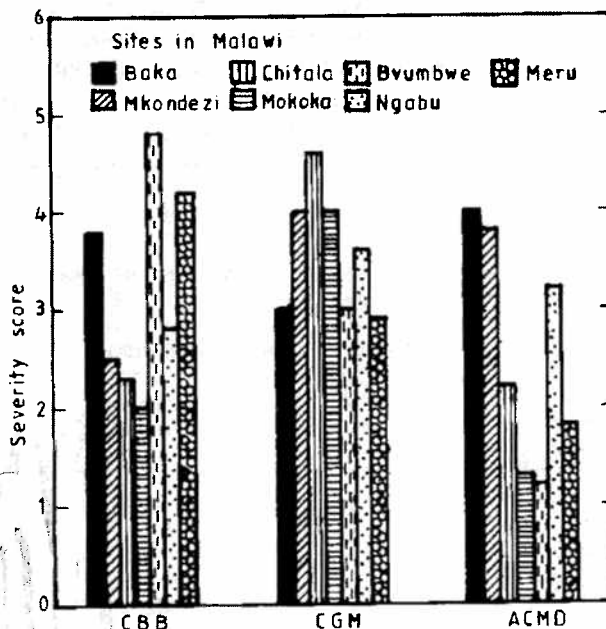


Figure 1. Severity of CBB, ACMD and damage symptoms of CGM on the same genotypes of cassava at seven different sites in Malawi.

*Severity score based on a 1-5 scale (1=no damage, 5 = high severity).

an early stage the full genetic sensitivity of the clone when infected. The data in the same table showed that most of the breeding clones become increasingly affected by ACMD and to some extent CGM in successive growth cycles.

The date and stage of growth on which pests are assessed in the field is very critical as symptoms

often disappear as the plants age (e.g. ACMD) or recover due to the effects of season (e.g. CGM). Figure 2 shows clearly that the best period for the evaluation of CGM damage symptoms at IITA in Ibadan, Nigeria is between mid-December and mid-January when mite populations tend to be high.

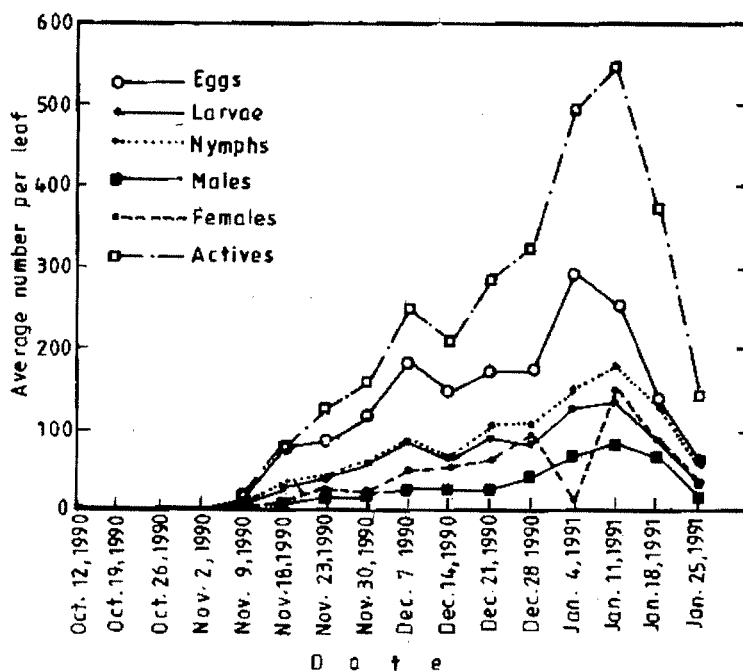


Figure 2. Cassava green mite population density monitored at weekly intervals on TMS 30001 during the dry season between October 12, 1990 and January 25, 1991 at IITA, Ibadan, Nigeria. 'Actives = larvae + nymphs + adults (males and females).

TABLE 2. Reactions of seven cassava genotypes to African cassava mosaic disease (ACMD) and cassava green mite (CGM) at Mkondezi, Malawi from 1990 to 1993

Clone	ACMD						CGM					
	1990/91		1991/92		1992/93		1990/91		1991/92		1992/93	
	Av. ¹	Max. ²	Av.	Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.	Max.
CH 90/0561	1.0	1.0	1.4	4.0	3.2	4.0	1.3	2.0	1.5	3.0	3.4	4.0
CH 90/0792	1.0	1.0	1.3	4.0	3.4	4.0	1.3	3.0	2.1	3.0	2.7	4.0
CH 90/0808	1.0	1.0	1.0	1.0	3.6	4.0	2.0	3.0	1.7	3.0	2.5	4.0
MK 90/1151	1.0	1.0	2.3	3.0	1.6	4.0	1.0	1.0	2.1	4.0	2.3	4.0
mk 90/1160	1.3	3.0	2.2	3.0	2.8	4.0	1.0	1.0	1.4	4.0	1.3	2.0
Mbundimali	2.6	4.0	3.6	5.0	3.0	4.0	1.4	3.0	1.3	4.0	1.3	4.0
Gomani	1.5	5.0	1.4	4.0	1.6	4.0	2.1	3.0	3.3	4.0	2.2	3.0

¹ Av. = Average score for all plants within a plot on a scale of 1 (no damage) to 5 (severe damage)

² Max. = Score of the most severely affected plant per plot

HOST PLANT RESISTANCE TO PATHOGENS AND PESTS

African cassava mosaic disease (ACMD).

ACMD can cause almost total loss in the yield of storage roots of diseased plants although reductions of 20-60% are more usual (Thresh *et al.*, 1994a). The aetiology of the disease is now well established and it is known to be caused by either of two whitefly-borne geminiviruses (Thresh *et al.*, 1994b; Harrison *et al.*, 1995). These viruses are readily transmitted by *Bemisia tabaci* Gennadius and they are also disseminated in cuttings of infected plants. Clone 58308, originally resulting from the research of Nichol and Storey in East Africa, was selected by Beck in Nigeria in 1958 (Beck, 1960, 1982), and was

identified as resistant to ACMD (Hahn *et al.*, 1977). Crosses between 58308 and local cultivars from Nigeria resulted in a number of useful ACMD-resistant cultivars. *Manihot glaziovii* has also been crossed to various cassava cultivars (local and improved) followed by selection for ACMD resistance at IITA and in other national programmes (Asiedu *et al.*, 1992, 1994).

Resistance to ACMD is reported to be multigenic or polygenic (Doughty, 1958; Hahn and Howland, 1972). The resistance appeared to be largely additive in nature with a heritability of about 60% (Hahn *et al.*, 1974), but Hahn *et al.* (1980b) later reported that resistance is recessive.

Selection efforts in Zaire (PRONAM, 1986) and Nigeria as illustrated in Figures 3 and 4, respectively, showed that good progress can be

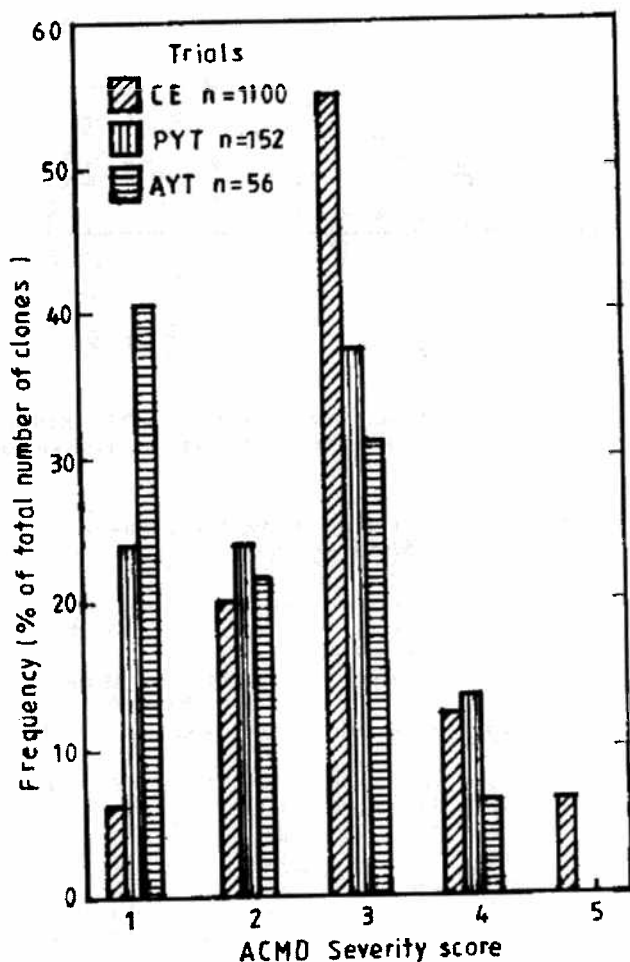


Figure 3. Distribution of plants into different symptom categories for ACMD severity for genotypes assessed at three successive breeding stages in M'vuazi, Zaire (1986). Severity score based on a scale of 1-5 (1 = no symptoms, 5 = high severity). CE = Clonal Evaluation, PYT = Preliminary yield trial, AYT = Advanced yield trial, n = number of clones assessed.

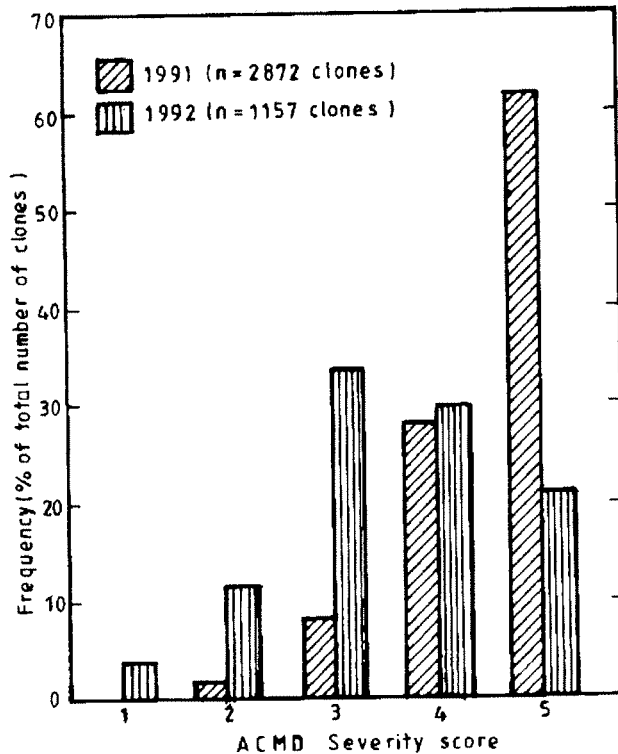


Figure 4. Yearly progress in selection for ACMD resistance in cassava as distribution of plants into each symptom category per year from 1991 to 1992 at IITA, Ibadan, Nigeria.

*Severity score based on a scale of 1-5 (1 = no symptoms, 5 = high severity); n = number of clones assessed.

obtained in breeding for ACMD resistance. Successive stages of the selection scheme had progressively lower ACMD severity scores. Genotypes with ACMD scores of 1-3 are generally selected in Zaire as leaves with mild mosaic symptoms are preferred by leaf consumers and they have greater market value than symptomless leaves.

Significant progress has been made in ACMD resistance as well as in yield and other agronomic characteristics. The improved ACMD-resistant populations and families in seed form and clones *in vitro* which were indexed as virus-free, have been sent to over 30 national programmes in Africa for evaluation and selection under their specific agro-ecologies and farming systems.

Cassava bacterial blight (CBB). Two types of bacterial disease affect cassava in Africa: *Xanthosomas campestris* pv. *cassavae* (cassava angular leaf spot) and *X. campestris* pv. *manihotis* (cassava bacterial blight) (Maraitte and Weyns, 1979; Lozano *et al.*, 1981; van den Mooter *et al.*,

1987). The former is of limited importance in Africa but the latter, the causal agent of CBB, has been reported in many African countries (Hahn *et al.*, 1989) and can result in complete yield loss where conditions favour disease development. The major means of spread of the disease is by movement of infected planting material and by rain splash (Lozano and Wholey, 1974; Anonymous, 1985; Boher and Verdier, 1994).

In Africa where there are distinct rainy and dry seasons, the disease cycle of CBB has angular leaf and epiphytic phases. The former begins soon after the first rains and continues during the main rainy period. It leads to wilting and defoliation of infected leaves, tip die-back and death of the plant in susceptible cultivars; the latter begins with the onset of the dry season. The pathogen survives the 5-6 month dry season as an epiphyte and increases in number when moisture becomes available (Persley, 1979). The optimal temperature for growth and development of *X. manihotis* is 30°C. Cassava bacterial blight severity, however, is higher in cooler areas where the average

temperature (day and night) is 20-25°C, and where night and day temperatures are 15-20°C and 28-30°C, respectively (Takatsu *et al.*, 1979).

Sources of CBB resistance were identified in Nigerian clone 58308 and in local cultivars and incorporated into improved cassava cultivars and breeding populations (Hahn and Howland, 1976; Perreaux, 1977; Hahn, 1978). The improved cultivars in the form of tissue culture and improved populations as seeds have been sent to many national programmes in Africa for selection under their own local conditions.

Resistance to CBB seems to be attributable to recessive quantitative genes which have mainly additive effects. However, there seem to be non-additive effects as well (Hahn *et al.*, 1974). The broad-sense heritability for CBB resistance was estimated to be 48% (Hahn *et al.*, 1989).

The CBB-resistant selections seemed not to be due to a hypersensitive reaction to the bacteria but rather to the restriction of bacterial multiplication and slow inactivation of the pathogen. Improved cassava varieties such as TMS 30211 and TMS 30555 showed a narrow range of variation and lower infection levels when they were inoculated with the isolates of *X. manihotis* from Nigeria, Zaire, Tanzania, Colombia and Brazil. Even more interesting was the lack of any genotype-pathogen isolate interaction (Perreaux, 1977).

Cassava anthracnose disease (CAD). Progress in enhancing the resistance of cassava to CAD, caused by *Collectotrichum gloeosporioides f. sp. manihotis* Henn (a weak pathogen) was limited until Muimba (1982) demonstrated a relationship between the CAD pathogen and a sap-sucking insect vector (*Pseudotheraptus devastans*). TMS 30211 and TMS 30555 were found to be resistant to CAD. A faster increase in peroxidase activity was observed in the resistant clone, TMS 30211, than in the susceptible TMS 30337. Peroxidase is involved in the last stage of lignin synthesis and in the development of the brown margin which is a defence mechanism of the plant against the pathogen.

Cassava green mite (CGM). CGM was first reported in Africa in Uganda (Nyiira, 1972), and now occurs in almost all cassava-growing countries of the continent. It is a prevalent pest

during the dry season and indigenous to Latin America (Belloti *et al.*, 1994; Yaninek, 1994).

Cassava green mite feeds initially on young leaves and shoots. Damage symptoms are characterised by yellow speckles, reduced leaf size and plant defoliation which may be followed by shoot die-back. Economic losses include the damage to the leaves used as a green vegetable and up to 80% reduction of storage root yield (Yaninek *et al.*, 1990).

The original sources of CGM resistance were identified from IITA breeding material tested in Tanzania, Nigeria and Zaire (Hahn *et al.*, 1980a). They have since been incorporated into susceptible but improved, high yielding and disease-resistant breeding parents and populations. Several cultivars with resistance to CGM, namely TMS 40764, TMS 42025, TMS 4(2)1425, TMS 30017, TMS 60142, TMS 61677 and TMS 91934, have resulted from this effort and are being used as parents in the breeding programme. Among the CGM-resistant clones, TMS 4(2)1425 and TMS 60142 confer high storage root yield (Hahn, 1982). Broad sense heritabilities of 71% to 79% were obtained for CGM resistance (IITA, 1982a).

The resistance of CGM was associated significantly with hair density on the upper and lower leaf surfaces, petiole and stem tips ($r = -0.56$ to -0.71). A high heritability of 93% was also obtained for pubescence (IITA, 1982a). The pubescence character appeared to be regulated by more than one pair of genes with a partial recessive effect (IITA, 1983).

The CGM-resistant clones and seed populations have been exchanged, following approved quarantine procedures, with many national cassava improvement programmes in Africa for testing and selection under local environmental conditions. These programmes include Nigeria, Sierra Leone, Liberia, Zaire, Gabon, Tanzania, Rwanda, Cameroon, Malawi, and Uganda.

The identification and continuous diversification of resistant sources to CGM followed by recombination and selection for improved cassava breeding populations with higher levels of multiple pest resistance is an on-going process. The results so far obtained are encouraging (Figs. 5 and 6).

Cassava mealybug (CM). CM is indigenous to Latin America. It was first reported in Africa in

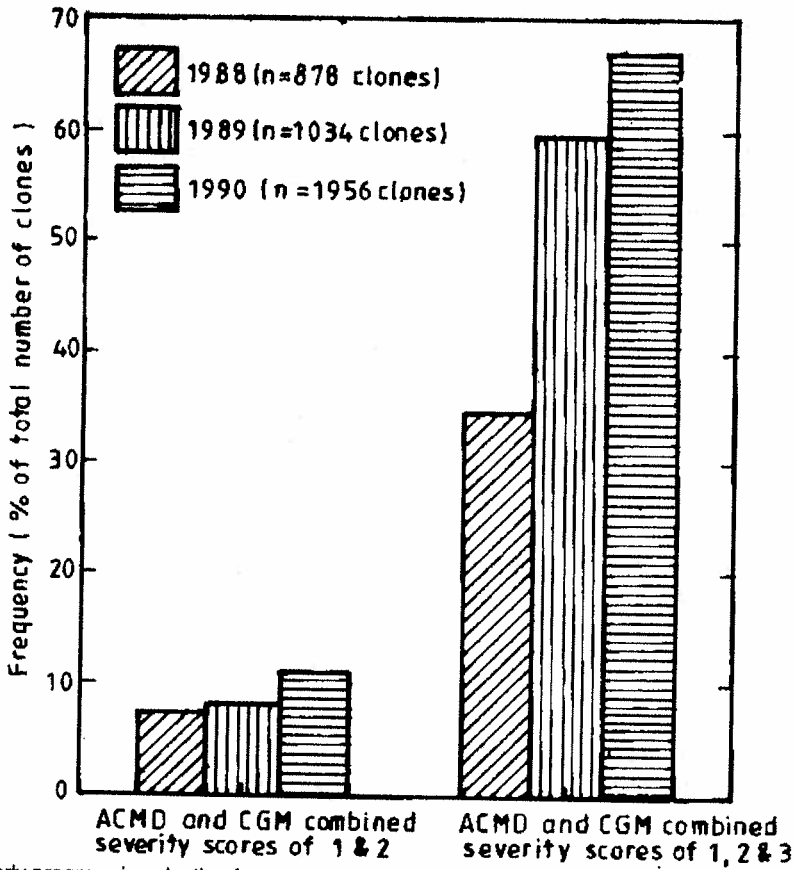


Figure 6. Yearly progress in selection for combined ACMD and CGM resistance in cassava as the distribution of clones in the low symptom categories of 1 and 2 and of 1, 2 and 3 for both pests from 1988 to 1990 at IITA, Ibadan, Nigeria.

*Severity score based on a scale of 1-5 (1 = no damage, 5 = high severity); n = number of clones assessed.

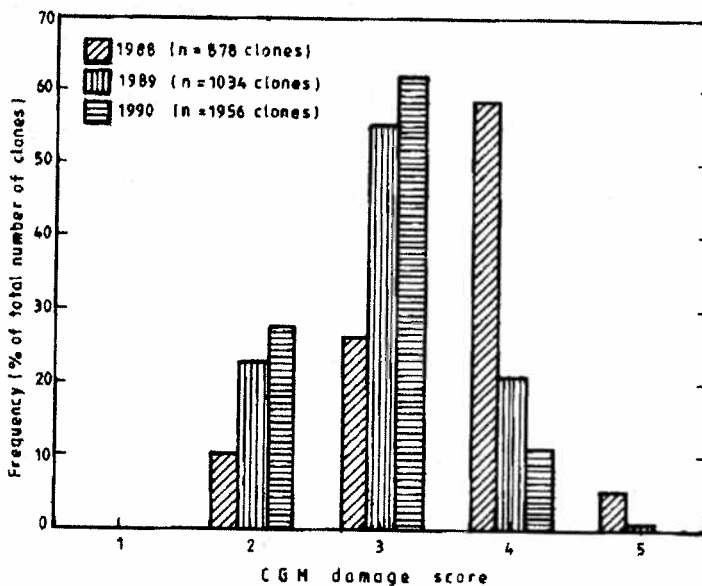


Figure 5. Yearly progress in selection for CGM resistance in cassava as distribution of plants into the five damage categories from 1988 to 1990 at IITA, Ibadan, Nigeria. Damage score based on a scale of 1-5 (1 = no damage, 5 = high damage); n = number of clones assessed.

Zaire (Hahn and Williams, 1973), but now occurs in all cassava-growing countries of the continent. Initially, the dual approach of resistance breeding and biological control was adopted to reduce the damage to cassava caused by this pest. Biological control successfully reduced the CM population within a relatively short time (Neuenschwander, 1994).

Sources of resistance to CM were identified from IITA breeding materials in Zaire and Nigeria. Among the CM-resistant clones TMS 4(2)1425 and TMS 60142 (both also resistant to CGM) gave high storage root yields (Hahn, 1982). A broad sense heritability of 97% was obtained for CM resistance (IITA, 1982a) and the resistance seems to be regulated by more than one gene (IITA, 1984). Resistance of cassava to CM was correlated significantly with hair density on the upper and under leaf surfaces, petiole and young stem tips ($r = -0.56$ to -0.62) (IITA, 1982a). An antibiosis form of resistance to CM has also been reported (IITA, 1982b).

PROSPECTS IN RESISTANCE BREEDING

New sources of resistance. More genetic resources from the cultivated species and its wild relatives are being used to diversify resistance and make further progress in pest resistance breeding. Numerous F_1 inter-specific hybrids produced at IITA are being evaluated for their reactions to the various pests as discussed by Asiedu *et al.* (1994). The hybrids include progenies from different accessions of *Manihot tristis*, *M. anomala*, *M. epruinosa*, *M. pholii* and *M. tripartita*. Progenies from *M. tristis* and one accession of *M. anomala* have dense pubescence on the young shoots (Asiedu *et al.*, 1992, 1994). Early indications are very encouraging. A total of 21 IITA improved clones as *in vitro* cultures were sent to Centro Internacional de Agricultura Tropical (CIAT), Colombia to be crossed with Latin American germplasm of diverse origin. The hybrid seeds were brought to IITA in 1990 and are being evaluated in various agroecologies in Nigeria. Selected progenies from this venture will be used to incorporate desirable characteristics into breeding populations for further selection and breeding for multiple pest resistance.

New sources of resistance to major economic diseases and arthropod pests have been identified among landraces in Africa. Cassava, being an open-pollinated and heterozygous plant, recombines in farmers' fields and also introgresses with related species, resulting in greater genetic variability. Farmers selection for adaptation to local conditions and utilisation has occurred and numerous varieties have emerged in Africa which are good sources of resistance to pests, have good quality traits, and are adaptable to the farming systems.

Integration of agronomic and consumer qualities with multiple pest resistance. Pest resistance is only one aspect of cassava improvement. Lines with good pest resistance are included in broad-based populations in specific agroecologies for cyclic selection of genotypes that combine resistance with good agronomic and consumer qualities. Several improved and local selections from landraces with different levels of resistance to major pests have been recommended and/or released in many African countries (Table 3). Also, many selections are undergoing evaluations in the advanced yield trials of the selection scheme which have higher levels of multiple resistance to most of the pests discussed in combination with good cooking/eating qualities and very promising yield levels.

Development and exchange of germplasm. Landraces of cassava from various national programmes have been an important resource for genetic improvement of cassava. Combined with exotic introductions from Latin America, the Root and Tuber Crops Improvement Programme of IITA and collaborators in national programmes have developed improved cassava genotypes by recurrent selection which combine multiple resistance to major pests of sub-Saharan Africa with desirable agronomic and food quality traits. Germplasm selected for such traits is shared within the region as improved seed populations or specific genotypes for evaluation and selection under specific local conditions. This takes into account the target agroecologies and the capacity of the national programmes to carry out the evaluation and selection.

Improved seed populations are distributed and

evaluated annually in several national programmes. Before distribution seeds are treated with dry heat at 60°C for 14 days and dusted with a fungicide (Benlate). Between 1988 and 1993 several thousand cassava seeds representing 487 families segregating for multiple pest resistance, high yield and quality (culinary quality, yellow roots, low cyanide, etc.) were distributed by IITA to 33 countries in sub-Saharan Africa for further evaluation and selection.

International exchange of improved vegetative propagules has been restricted to material derived from meristem culture (*in vitro* plantlets) that are virus-tested and certified by plant quarantine authorities. Annually, these genotypes are distributed to meet national programme requests. National technicians are also trained in the handling of tissue culture-derived materials until they become established in the field. For example in 1993 five consignments of 300-400 plantlets, each comprising 50 cassava clones were delivered to and established in Cameroon, Gambia, Niger, Burkina Faso, Cape Verde and Chad.

Role of host plant resistance in an ecologically sustainable cassava plant protection strategy.

Varietal resistance of cassava should serve as a component of an integrated pest management control strategy to combat the various pests. Host plant resistance has several advantages: it is economical for the farmers, specific to the target species, leaves no harmful residues in food or the environment and it may be compatible with biological, chemical and other control methods. Thus, it offers an environmentally sound and sustainable basis for integrated programmes for pest control.

Several new sources of resistance to CGM have been identified and are incorporated into high-yielding but susceptible elite clones and populations at IITA and national programmes. Additional sources, both local and exotic, are being sought to diversify sources of resistance to the major pests and also combine different genes that control various mechanisms or the same mechanisms of pest resistance. This may result in additive or epistatic interactions that will give higher levels of resistance in elite cassava populations. The current breeding effort is planned to provide an efficient breeding strategy for transfer of resistant genes into populations to give multiple pest resistance through the agroecologically-based population improvement schemes.

TABLE 3. Cassava varieties released/recommended by National Programmes for adoption by farmers

Country	Recommended genotypes/released cultivars
Benin	TMS 30572, TMS 4(2)1425, TMS 30572A, BEN 86052
Burundi	40160-1, 40160-3
Cameroon	8034, 8017, 8061, 820516, 1005, 658, 244
Côte d'Ivoire	TMS 30572, TMS 4(2)1425
Gabon	CIAM 76-6, CIAM 76-7, CIAM 76-13 and CIAM 76-33
Gambia	TMS 60142, TMS 4(2)1425
Ghana	TMS 30572, TMS 50395, TMS 4(2)1425
Guinea Conakry	TMS 30572, TMS 4(2)1425
Guinea Bissau	TMS 4(2)1425, TMS 60142
Liberia	CARICASS 1, CARICASS 2, CARICASS 3
Malawi	Mbundumali, Gomani, Chitembwe
Mozambique	TMS 30001, TMS 30395, TMS 42025
Nigeria	N.C. Idi-ose (TMS 30572), N.C. Savanna [TMS 4(2)1425], TMS 91934, TMS 90257, TMS 84537, TMS 81/00110, TMS 82/00058, TMS 82/00661
Rwanda	Gakiza, Karana and TMS 30572
Seychelles	SEY 14, SEY 28, SEY 32, SEY 41, SEY 52
Sierra Leone	ROCASS 1, ROCASS 2, ROCASS 3, NUCASS 1, NUCASS 2, NUCASS 3, 80/40, 86/1
Togo	TMS 4(2)1425 and TMS 30572
Uganda*	NASE 1 (TMS 60142), NASE 2 (TMS 30337), and MIGYERA (TMS 30572)
Zambia	LUC 133
Zaire	Kinuani, F100, 40230/3, 02864 and Lwenyi/3

* See Otim-Nape *et al.* (1994) for further details of the introduction and performance of these varieties.

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