ROOT CROPS IN EASTERN AFRICA

Proceedings of a workshop held in Kigali, Rwanda, 23-27 November 1980
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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa, Canada

International Institute of Tropical Agriculture, Ibadan NG
International Development Research Centre, Ottawa CA


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Root Crops in Eastern Africa

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Cosponsored by Gouvernement de la République rwandaise, the International Institute of Tropical Agriculture, and the International Development Research Centre.
Résumé

Cette brochure traite principalement des deux tubercules alimentaires les plus importants en Afrique orientale, soit le manioc et la patate douce. Quelques communications portent sur la pomme de terre, l’igname, le taro et l’- enset - dont la consommation est considérable dans plusieurs pays de la région. Le rendement de ces cultures est limité par de nombreux facteurs. Aussi, la recherche effectuée dans le cadre de programmes agronomiques nationaux et internationaux est-elle orientée vers la correction de cette situation en Afrique. Les difficultés rencontrées en cours de travaux et les progrès réalisés sont décrits par des représentants et des consultants de l’Institut international d’agriculture tropicale d’Ibadan (Nigéria) et d’autres pays tel que le Cameroun, le Kenya, l’Ouganda, le Malawi, le Zimbabwe, l’Éthiopie, le Burundi, le Zaïre et le Swaziland.

Resumen

Esta publicación se enfoca en la mandioca y el camote — los cultivos de tuberosas más importantes del Africa oriental. Los trabajos tratan también del Solanum tuberosum, Dioscorea spp., Colocasia sp., Xanthosoma sp., y Enset sp., que son todos cultivos importantes a los países de esta región. La producción de cada uno es restringida por serios constreñimientos, y el alivio de éstos es el objetivo de varias investigaciones llevadas a cabo por los programas agrícolas nacionales e internacionales en el Africa. El progreso hacia y los problemas encontrados en llegar a este fin son delineados por especialistas representando al Instituto Internacional de Agricultura Tropical en Ibadan, Nigeria, y a los países de Camerún, Kenia, Uganda, Malawi, Zimbabwe, Etiopia, Burundi, Zaire, y Swazilandia.
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Increasing and stabilizing cassava and sweet-potato productivity by disease resistance and crop hygiene

E.R. Terry and S.K. Hahn

Vegetative propagation encourages the perpetuation and dissemination of the major disease agents affecting cassava and sweet potato. This article describes the major virus and bacterial diseases of both crops with special reference to Africa. Data on crop-yield reductions caused by the diseases are also reviewed. Evidence of host-plant resistance to cassava mosaic and cassava bacterial blight diseases and to the sweet-potato virus disease is presented and reviewed. The possibilities for integrated disease control by the use of the available levels of disease resistance, together with sound crop hygiene, to increase and stabilize the yields of both crops are set forth.

La multiplication végétative est un facteur de perpétuation et de dissémination des principaux agents responsables des maladies du manioc et de la patate douce. L'article décrit les principales viroses et maladies bactériennes qui frappent les deux cultures, surtout en Afrique. On passe en revue les données sur les baisses de rendement dues aux maladies, ainsi que la résistance des plantes hôtes à la mosaïque et la brûlure bactérienne chez le manioc, et à la virose chez la patate douce. On présente les possibilités d'une lutte intégrée contre ces ennemis au moyen des degrés possibles de résistance et d'une bonne hygiène des cultures pour accroître et stabiliser les rendements de ces deux plantes vivrières.

Cassava (Manihot esculenta) provides more than 50% of the caloric requirement for 200 million inhabitants in Africa and for 420 million in the world. The total annual cassava production of $4.2 \times 10^8 \text{ t}$ in Africa constitutes 40% of the global production (FAO 1977).

Sweet potato (Ipomoea batatas) is also an important staple food in many parts of the tropics and subtropics. In addition to its importance as human food, this crop provides animal feed and raw material for industrial purposes. The global production figures show that Africa, producing roughly 4% of the total world output of $1.3 \times 10^9 \text{ t}$, is the second largest producer (FAO 1977).

The incidence and the severity of major economic diseases of cassava and sweet potato limit their productivity both in terms of their high caloric potential and the high protein content of the leaves of both crops, which constitute a significant part of the diet of a large percentage of Africans in Zaire, Sierra Leone, Tanzania, Cameroon, Liberia, and the Congo.

Perpetuation and dissemination of the diseases

Vegetative propagation of cassava and sweet potato provides a highly efficient mechanism for the perpetuation and dissemination of the causal agents of the major economic diseases of the two crops. This is particularly true of the viruses and bacterial pathogens (Terry 1978d).

Of the major virus-like diseases (Table 1) of cassava, the two most important in Africa are cassava mosaic disease (CMD) and cassava brown streak virus (CBSV).

Storey and Nichols (1938) demonstrated that the CMD agent (tentatively believed to be a virus) was carried in cuttings of diseased plants and was transmissible across a graft and by means of an insect vector (Bemisia spp.). Storey (1936) first recorded and de-
The other viruses and virus-like diseases of cassava are also perpetuated and disseminated by propagation of infected woody stem cuttings (Lozano 1977). Although they are at present restricted in their distribution to parts of South America, the potential for their introduction into the African continent is great.

The major virus diseases (Table 2) of sweet potato are not well understood at present. The relationships between the sweet-potato virus disease (SPVD) complex as described by Schaefers and Terry (1976) and the virus diseases described by Sheffield (1967) and Hollings et al. (1976) remain unclear. Part of the confusion arises from the wide varietal differences in reactions of sweet potato and from complex infections with two or more viruses. Furthermore, some of the viruses involved in these complexes remain inadequately characterized.

Sheffield (1953) reported field observations indicating that the sweet-potato viruses were carried in vine cuttings (primary infection). All the adequately studied sweet-potato viruses have also been shown to be transmitted by grafting, and some are also transmitted (with difficulty) by sap inoculation (PANS).
Schaefer and Terry (1976) reported two components of the SPVD complex in Nigeria, namely a vein-clearing virus transmitted by aphids in a nonpersistent manner and usually latent in sweet potato and another latent virus transmitted by the whitefly (Bemisia tabaci). In combination, the two disease agents produce severe symptoms in sweet potato.

Of the major bacterial diseases of cassava (Table 3), cassava bacterial blight caused by Xanthomonas manihotis has been reported from West Africa (Terry 1978c), and both X. manihotis and X. cassavae have been reported from Kenya (Onyango and Ramos 1978) and Rwanda (Maraite and Perreaux 1978).

Xanthomonas manihotis is a vascular pathogen that can be disseminated through vegetative planting material (Lozano and Sequeira 1974). Although X. cassavae was originally reported as inducing only leaf spots (Wiehe and Dowson 1953), it is also possibly disseminated by vegetative propagation of infected woody stems. Xanthomonas manihotis also could be disseminated by movement of soil during cultural operations or by the use of contaminated tools, especially in view of the extensive amount of cutting that is required during harvesting and preparation of planting material (Lozano 1975). Studies on the role of insects in the dissemination of this pathogen revealed that spread attributable to insects only occurred over short distances (Lozano and Sequeira 1974).

The two other cassava bacterial pathogens, Erwinia carotovora var. carotovora (bacterial stem rot) and Agrobacterium sp. (bacterial stem gall), have been reported only in the Americas but have a high-risk potential for introduction into Africa as well.

Two bacterial pathogens have been reported for sweet potatoes: Pseudomonas bata, which causes a wilt in China (Faan et al. 1959), and Erwinia spp. causing wilt and plant death in the United States (Martin and Dukes 1975). Both of these bacteria are disseminated through diseased vines (Nielsen and Terry 1977).

**Yield losses**

**Cassava mosaic disease**

The symptoms of CMD are characteristic of a mosaic disease, primarily chlorosis of discrete areas of the leaf lamina. Leaf-area reduction is reported to be about 24% (Beck and Chant 1958), and severely affected leaves are twisted and distorted. Cassava mosaic disease induces increases in the respiration rate and in the peroxidase activity in cassava leaves and reduces photosynthetic activity of mature infected leaves by 23%. Chloroplasts in the mesophyll cells of infected leaves are irregularly shaped and contain numerous swollen starch grains (Chant et al. 1971).

Jennings (1972) estimated that the yield losses caused by cassava mosaic in some locales in East Africa ranged from 65% to 95%. Bock and Guthrie (1978) reported that, in Kenya, the mean loss from CMD in a moderately resistant hybrid was 70%, and, in a

<table>
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Adapted from Lozano (1977).
susceptible cultivar, it was 86%. We (1980) found that, in Nigeria, the mean fresh-root weight reduction caused by CMD ranged from 32% to 69% and that the starch-content reduction was 2.5–7%.

**Cassava brown streak virus**

Symptoms of CBSV occur in leaf, stem, fruit, and root tissue. The main leaf symptom is chlorosis, whereas stem symptoms consist of brown streaks that elongate and coalesce with adjacent streaks to form blotchy patches. Necrotic lesions can also be observed in leaf scars after leaves have been shed. Root infection results in the formation of necrotic lesions in the tuberous starch-storage tissues (Nichols 1950).

Because CBSV and CMD invariably occur together in the coastal regions of East Africa, it has not been possible to determine the yield loss owing to CBSV alone; however, the extensive root necrosis renders tuberous roots unfit for human consumption (Jennings 1972).

**Cassava bacterial blight**

The characteristic symptoms of CBB include angular water-soaked leaf spots, which are initially small but later enlarge, coalesce, and eventually turn brown; various degrees of leaf wilt; the exudation of a yellow-orange gum on the leaves, petioles, and young shoots; severe defoliation; and finally stem dieback resulting from vascular necrosis and death of growing tips.

Cassava bacterial blight is considered the most devastating of several bacterial diseases of cassava because it can result in total loss of both yield and planting materials of a susceptible variety (Lozano and Sequeira 1974). Under favourable conditions for disease development in areas where the leaves are consumed, the heavy loss of foliage constitutes a significant economic loss (Terry 1978c). Tuberous root-yield losses have been reported as 7–75% in Colombia (CIAT 1975); 58% in Ibadan, Nigeria (IITA 1977); and 90% in Umudike, Nigeria (O.B. Arene, unpublished). Reduction of tuberous-root starch content because of CBB has also been reported (Obigbesan and Matuluko 1977).

**Sweet-potato virus disease**

Symptoms of the sweet-potato virus disease consist of various combinations of leaf strap-
developed at IITA were tested during 1973–78 in West, Central, and East Africa and proved effective. The absence of regional differences in terms of effectiveness of this resistance and its polygenic nature suggest that it is durable over time and distance (Hahn et al. 1980). Whether the resistance is race-nonspecific is not yet clear, but information on pathogenic variation should provide an answer.

With regard to CBB, the high level of resistance of IITA-improved varieties to this disease was confirmed by stem-puncture, leaf-clipping, and leaf-spray inoculation tests (Perreaux et al. 1978) and is well correlated with the results of natural infection (IITA 1976). Highly tolerant varieties only exhibit angular leaf spotting under natural infection and rarely show the degree of defoliation and stem dieback associated with susceptible varieties. Resistant varieties may have a relatively high number of leaf spots per leaf, but these are normally very small and do not coalesce to form large spots.

**Sweet-potato virus disease**

Hahn et al. (1981) reported that, in field trials, in four locations in Nigeria, four sweet-potato cultivars showed high levels of field resistance to SPVD. A high correlation between field SPVD severity scores and scores recorded after a positive challenge by the root-graft transmission method confirmed the resistance level of the IITA-improved varieties.

Individual plants of the resistant varieties were challenged with virus-carrying core tissues, and, although the test varieties expressed symptoms, there was evidence that these varieties had the capacity to grow vigorously and recover from infection. Only small numbers of plants of resistant cultivars were positively challenged by this method, and there were significant differences in time interval for onset of symptoms (Terry 1979). These observations indicate that the nature of resistance is associated with resistance to infection.

**Disease control by crop hygiene**

Results of field observations and experiments in Kenya suggest that CMD can be controlled by the use of mosaic-free planting material. The low rate of spread of mosaic into mosaic-free plots, and also within plots, indicates that whiteflies are comparatively inefficient vectors and that human beings are the principal vector because of their indiscriminate use of infected cuttings as propagation material (Bock and Guthrie 1978). Lozano and Terry (1976) suggested that the incidence of pathogens and the damage they cause to cassava propagation material could be reduced by a careful selection of all planting material. The use of cuttings from plantations with CBB infection must especially be avoided, and any stem sections with signs of disease should be eliminated.

Sheffield (1953) reported similar findings for sweet potato — that the increase of SPVD by the vector was normally slight in the field — and suggested that the more important damage arises from propagation by infected vines. The merits of utilizing pathogen-free planting material especially for vegetatively propagated crops, to minimize crop losses, are well recognized (Hollings 1965). The strategy is to dilute the amount of virus or bacterial infection by the supply of large quantities of healthy planting material to facilitate replacement of reinfected stock.

**Integrated disease control**

The success of any control practice based on utilization of pathogen-free planting material depends largely on the incidence and magnitude of subsequent field reinfection by the major pathogens of the crop. Subsequent field reinfection is influenced in turn by the varietal susceptibility of the planting material, the virulence of the relevant pathogens, and the existence of favourable environmental conditions for disease development.

We (1980) reported earlier that the improved CMD-resistant cassava variety TMS 30395 produced significantly higher root yields under field conditions than its susceptible parent Isunikakiyan irrespective of whether it was established from mosaic-free or mosaic-infected planting material. Under conditions in Ibadan, Nigeria, the CMD-resistant TMS 30395 yielded an average of 2.96 kg fresh roots/plant when established from CMD-free cuttings compared with 2.02 kg/plant from CMD-infected cuttings. The CMD-susceptible variety Isunikakiyan yielded 1.43 kg/plant when established from CMD-free cuttings, compared with 0.44 kg/
plant from CMD-infected cuttings. Furthermore, the rate of increase in CMD incidence on TMS 30395 established from CMD-free planting material was low, reaching a peak of 17.4%, 5 months after planting, compared with 99% for Isunikakiyan. It appears, therefore, that an important component of resistance to CMD is resistance to reinfection by the B. tabaci vector.

This type of resistance, which results in low field incidence of CMD in resistant varieties like TMS 30395, can be exploited for the possibilities it offers for maintaining a CMD-free crop yielding an average of 29 t/ha, the farmer roguing out the small number of plants that become infected. These plants can then be routinely replaced by CMD-free plants of the same cultivar from a disease-free stock.

Hahn et al. (1981) reported that the IITA-improved sweet-potato varieties resistant to SPVD can also yield an average of 20–30 t of roots/ha in 4 months without fertilizers. Furthermore, in field tests, one of the resistant varieties, TIS 2498, had a low SPVD severity rating and only a small increase in incidence.

The aphid-transmitted filamentous particles of the SPVD in Nigeria can, with difficulty, be mechanically transmitted from sweet potato to Nicotiana benthamiana, inducing leaf crinkling and puckering, but not to sweet potato (IITA 1978). In East Africa, a virus obtained from sweet potatoes in Kenya, Uganda, and Tanzania was transmitted by inoculation of sap and by whiteflies (B. tabaci) to sweet potato and other plant families (Hollings et al. 1976). In Nigeria, however, although large populations of whiteflies and aphids have been reared in captivity on sweet potatoes, field infestation levels are rather low, and it appears that field-transmission efficiencies of SPVD by these vectors are also quite low (Hahn et al. 1981). In Ibadan, Nigeria, it normally takes 1–3 years for seedlings to develop severe SPVD under field conditions. Hahn (1979) reported that most of the symptomless plants used as disease-free controls in trials for yield comparison between SPVD-infected and disease-free plants remained symptomless until harvested 4 months after planting. The evidence, therefore, indicates that farmers, by propagating vine cuttings from infected sweet-potato plants, are the principal vector of SPVD.

The low rate of disease spread in disease-free plants of resistant varieties offers the possibility for farmers to maintain an SPVD-free crop, yielding an average of 20–30 t/ha, and to rogue out the small number of plants that become infected.