



Improving cassava for enhancing yield, minimizing pest losses and creating wealth in sub-Saharan Africa

Rodomiro Ortiz

CIMMYT, Apdo. Postal 6-641, 06600 Mexico, D.F., Mexico

Cassava (*Manihot esculenta*) became the most important food crop in sub-Saharan Africa, which accounts for most of the root harvest worldwide, followed by Asia and Latin America –the center of origin for *Manihot* species. The Portuguese brought cassava to Africa in the late years of the 16th Century (Jones 1959). The crop became widespread in Africa, especially in locations with high population density, such as southern Nigeria, western Democratic Republic of Congo, and eastern and northern Tanzania, where the crop remains an important staple for their inhabitants' food security (IITA 1992).

Due to its resilience in marginal environments, cassava can be grown in drought-prone locations, or in acid soils, which explain the role of this crop in alleviating faming, especially among the resource poor. In Africa and Latin America cassava is mostly used for human consumption, while in Asia and parts of Latin America it is also used commercially for the production of animal feed and starch-based products. Roots are processed into granules, pastes and flours or eaten freshly -boiled or raw. A dry cassava leaf contains up to 40% of crude protein but it may vary across cultivars (Lancaster and Brook 1983). The leaves are therefore eaten in Africa and some Asian locations as a green vegetable, which provides protein and vitamins A and B.

This article provides an overview on cassava research in sub-Saharan Africa considering that an effective means to alleviate poverty, and in turn its inseparable partner hunger, is through agriculture and the production of more nutritious and profitable food. As pointed out by the Director General of the International Institute of Tropical Agriculture (IITA) Hartmann (2004), “a successful approach cannot only be about agriculture —it has to recognize the vital role it plays in the bigger picture. The strength of the IITA approach of local production, wealth creation, and risk reduction, is its

embrace of strategies that recognize that the issues that contribute to poverty are intertwined. The degree of impact from this approach depends on several factors, not least of which is investor and implementing entity choices. The choices investors make in how activities are financed may be as important as how much. Equally, the choices made by development institutions such as IITA and its national and regional partners on problem definitions and research-for-development methods, are also critical.”

Producing locally

The argument for local production can be viewed from several perspectives. Hartmann (2004) argues for local production because it is the most stable way to improve livelihoods, increase food security and contribute to long-term and broad-based economic growth. By taking this approach, any research-for-development undertaking also addresses food security issues, which are directly related to poverty. As Hartman (2004) points out that *“focusing on local production is also needed because the alternative is food imports and that is not without limitations because such an approach does not fully accommodate nuances of geopolitics, climate, food preferences, global and regional trade, availability of foreign currency as well as available information and infrastructure. More importantly, the import approach does not address what is desired by the developing world and what is available from the industrialized world.”*

It was therefore not surprising that cassava research in Africa started in the 1930 by focusing on two central constraints to local production, namely African cassava mosaic virus (ACMV), and low yield of cassava, to which ACMW contributed. ACMV (later known as CMD or cassava mosaic disease) spreads by an insect vector and further distributed by infected plant cuttings, whereas low yield results from the use of poor planting materials and lack of access by farmer to bred-cultivars (IITA 1992). Breeding for ACMV began in Ghana, Kenya and Tanzania in the 1930s, and some hybrid clones ensue from crosses between cassava and *M. glaziovii* (Nassar and Ortiz 2006). Clones such as Gold Coast Hybrid 7 (GCH-7 bred in Ghana) and 5318/34 (bred at Amani, Tanzania) were brought to the Moor Plantation (Ibadan, Nigeria) in the 1940s and 1950s as source material for further cassava breeding, particularly for host plant resistance to ACMV. One of the clones selected in Nigeria was 58308 – an important source of new hybrids bred in the 1970s by IITA such as TMS 30572 and TMS 4(2)142, which are still widely grown in the Nigerian cassava belt and other African locations.

The overall rationale, in the mind of IITA founders, for establishing this Institute as an international high quality research organization in sub-Saharan Africa, was to find ways to enhance yields and quality of tropical food crops such as cassava. The research domain included all aspects that allow increasing and improving the quality of food. In the early years (1970s), IITA's agenda was organized into four programs; being one of them the Root and Tuber Improvement Program that was led by Dr. Sang Ki Hahn (Ortiz 2004). When Hahn arrived in Ibadan in 1971 to establish this program at IITA, he rightly saw that no amount of research effort would increase cassava yields until the problem of CMD was solved.

Hahn recognized the enormous implications of an endemic disease aggravated by humans through the use of diseased cuttings, and he focused cassava research tightly on this disease problem (Hahn et al. 1989). With Eugene Terry as pathologist, Hahn began the arduous task of searching the germplasm for resistance characters and then combining those characters with lines having desirable yield and quality factors (Hahn et al. 1980a). Fortunately, Hahn had access to the mosaic resistant families developed from A.J. Storey's work in East Africa nearly 30 years before and that of Brian Beck at Moor Plantation in the 1950s. However, these families had very poor root yields. He also brought cassava germplasm from Asia and South America. The latter incorporated wild *Manihot* genes that were initially bred by Prof. Nagib Nassar (Univ. of Brasilia) and other researchers in Brazil. It remained the IITA team's task ably assisted by Audrey Howland, an outstanding breeding research associate, to cross, select, clone, challenge, rogue, and select, beginning each season with up to 10,000 seedlings, until the desired level of resistance was incorporated into "elite" IITA cassava breeding materials (Fig 1).

In the early 1970s, cassava bacterial blight (CBB) was reported in Nigeria, and this 'black disease', as known by Nigerian farmers –particularly in eastern and mid-western states, caused huge crop losses because the best available cultivars (60444 and 60447) proved to be very susceptible (IITA 1992). Afterwards CBB epidemics were observed in a dozen African countries because their local cultivars were also susceptible to this disease. The clone 58308 –with low cyanide potential and resistance to ACMV, was also used as a source of resistance to CBB. An important genetic enhancement research finding was that CBB resistance derived from *M. glaziovii* was associated to with resistance to CMD (Hahn et al. 1980b). Furthermore, this IITA breeding endeavor led to new hybrid clones with resistance to CBB and ACMV, plus high yield and acceptable quality traits (Hahn et al. 1989). This breeding success ensued from the use of cassava clones brought from other continents, which were included in crossing blocks along with IITA disease-resistant clones, local African landraces, and the strong partnership research with the National Root Crops Research Institute (NRCRI) at Umudike, southeastern Nigeria (IITA 1992). The Centro Internacional de Agricultura Tropical (CIAT, Cali Colombia) also facilitated the acquisition by IITA of new parental materials, especially those grown in South America or suitable for dryland areas.

In summary, the target of this cassava breeding strategy was broadly based breeding populations that would be further selected by national researchers and local partners according to their needs (Jennings and Iglesias 2002). Hence, crosses among local cultivars was high in the Institute's breeding agenda as well as incorporating judiciously exotic germplasm into the desired gene complexes, but minimizing inbreeding and restoring heterozygosity to escape from inbreeding depression (Ortiz et al. 2006). The improved cassava germplasm was sent for testing across African locations through *in vitro* methods for elite genotypes, or as seed for half-sib and full-sib recombinant breeding populations. Furthermore, as indicated by Robinson (1995), the concept of farmer participatory schemes for plant breeding was initiated by Hahn and co-workers, who enlisted the help of small country schools in many West African locations with whom they shared some seeds of their promising materials.

Minimizing risk

Producers face risks that need to be managed. The poorer the farmers, the more limited their ability to deal with these risks. Addressing them, Hartmann (2004) says, is an important strategy for poverty reduction. He further indicates that *“like anyone else, farmers, rural families, and the poor try to avoid or reduce their risks. Poor farmers consistently attempt to diversify their sources of income by working part time. Knowledgeable about climatic risks, they not only grow different crops, but also grow them in different locations. Unfortunately farmers’ excellent strategies often let them down because the tools at their disposal and their ability to respond to risks are limited. Farmers are confined to certain localities and have limited purchasing power and very low asset base. Droughts, for example, affect not only the different locations where crops are grown, but also other agricultural activities in the area. The result is that alternative employment opportunities are reduced at the very time farmers need them most. So in spite of remarkable levels of knowledge and creativity, farmers’ responses to risks are limited. Thus the second line of this approach is devoted to supplementing risk management efforts. Here is a critical point where investor choices determine options.”* The risks faced by producers and rural communities fall into four broad groups: biological, commercial, natural and political. In the decision process under a risk-minimizing agenda should give preference to research-for-development methods that are less dependent on policies, inputs, costly government programs and services.

In this regard, cassava appears as an important crop option for marginal environment (e.g. drought-prone locations), where cereals and other species do not grow well, and it also grows well in poor soil (Ortiz and Hartmann 2003, Nassar and Ortiz et al. 2006). Under drought stress, the cassava plant reduces water use by following an avoidance strategy of stomatal closure and leaf area reduction. After the stress, recovery of cassava leaf area occurs, which, of course, influences root yield in cassava depending on the developmental stage of the crop and the environment where it grows. Because cassava roots can be stored in the ground for up to 24 months, and some cultivars for up to 36 months, harvest may be delayed until market, processing, or other conditions are favorable.

The successful biological control of crop pests in cassava is another example of this approach for minimizing risk in the cropping systems of sub-Saharan Africa (Neuenschwander 2004). The prerequisite for the success of such very knowledge-intensive programs is the nature of investor support and financing. It is difficult to implement biological control options successfully without long-term commitment to knowledge generation.

Cassava mealybug was one of the most serious pests for this crop, especially during the 1970s and 1980s because it destroyed producing fields and local sources of planting materials to such an extent that production practically came to a halt (IITA 1992). Led by Drs. Hans R. Herren and Peter Neuenschwander, entomologist and insect ecologist respectively, the IITA biological control team went well beyond the scope of most biological control projects in formulating the scientific explanation for the behavior of the host plant (cassava), the enemy (mealybug) and the control agent (beneficial parasite or predator). Several significant contributions to the body of scientific knowledge were made by this IITA team

(Neuenschwander 2001). These contributions include: the identification of the cassava mealybug as a newly introduced pest into Africa; the location of the same mealybug species in its area of origin in South America (in collaboration with CIAT entomologist Anthony Bellotti); the successful rearing of cassava mealybugs as well as their imported natural enemies in the laboratory at IITA; the migration and dispersal data assembled after the release of the beneficial parasite *Anagyrus* (*Apoanagyrus*, *Epidinocarsis*) *lopezi* –a predator wasp, the impact studies (rarely attempted exclusion experiments and population dynamics and biological data on both pest and parasite or predator); and the development of a simulation model showing plant/pest/predator-parasite interactions (Herren and Neuenschwander 1991). The introduced parasitoid *A. lopezi* dispersed, and controlled the cassava mealybug wherever it was released. For control stability, a complex of natural enemies is more desirable than a single species. The IITA team gathered considerable data on several mealybug predators, but none has shown the survival and dispersal qualities of *A. lopezi*. As a result of this effort cassava mealybug is now held in check across most of the African's cassava producing areas (IITA 1992). The spectacular control of the cassava mealybug was the first of many successes in the history of the Biological Control Center for Africa set up by IITA at Cotonou (Benin Republic) in the 1980s.

After cassava mealybug was brought under control by the introduced predator wasp *A. lopezi*, IITA researchers undertook the biological control of cassava green mite (Dixon et al. 2003). This pest was accidentally introduced into Africa in the 1970s and within a decade spread across Africa's cassava belt (Yaninek and Herren 1988). The major achievements in the cassava green mite research until the late 1980s was the establishment of the mite's true identity, its behavior within the cassava ecosystem, and its damage to the cassava plant (Mégevand et al. 1987). It was in the second half of the 1990s that IITA researchers J. Steve Yaninek and Rachid Hanna succeeded with classical biological control of cassava green mite by identifying, introducing and establishing predatory mites (*Typhlodromalus aripo* and *T. manihoti*) and later an acaropathogenic fungus (*Neozygites tanajoae*) from climatically similar areas of Brazil. Where the predatory mites have been continuously present for at least two years, cassava green mite density declined by 30 to 60% and cassava yields increased between 15 and 35%, with two cases of 62 and 85% increase in yield. The addition of the fungus *N. tanajoae* has led to further 25% decline in cassava green mite populations. This cassava green mite biocontrol campaign is continuing in Central, Eastern and Southern Africa with the addition of strains of predatory mites adapted to mid-altitude agro-ecologies, and the emphasis on the integration of cassava cultivars suitable to predatory mites (a relatively nascent dimension of biological control in general), owing to the sensitivity of *T. aripo* to specific morphological characteristics of the cassava apex where the predators reside during much of the daylight hours.

IITA successes on biological control of cassava pests rely on the strong partnership with national programs in sub-Saharan Africa. National capability was enhanced in the last 2.5 decades by intensive training of crop protection workers, after creating awareness among decision makers that there are alternatives to the use of agrochemicals for control of crop pests. The philosophy of this IITA capacity building approach for ecologically sound pest management considers that the ultimate goal is to strengthen national capability in biological control and not just secure resources for a single control campaign (IITA 1992). In this endeavor, IITA engaged the United Nations Development Program and the Food and Agriculture Organization as well as other investors of international aid to develop national biological control units in Africa and their continuous support by providing materials, financing and technical assistance.

Creating Wealth

The wealth creation concept according to Hartmann (2004) “*is to take what farmers already produce and use it to earn more income. They can be helped to sell it at the next rung on the ladder.*” If farmers increase crop production, a sound research-for-development agenda should create outlets for their produce. Simple agro-processing of crops such as cassava can double or even triple incomes (Dixon et al. 2003). Similarly dual-purpose use for food and feed leads commodities into other users and places, which provides another powerful poverty reduction concept: the expansion of markets through the creation of new outlets contributes to price stabilization without the need for costly government programs.

In view of the importance of cassava as a major source of calorie for Nigerians and potential source of large scale agro-industry uses in the country, the Federal Government of Nigeria asked IITA in 2002 to implement a cassava mega-project to preempt an outbreak of a more virulent strain of CMD (Dixon et al. 2002). This call was the result of a timely warning by IITA researchers on the potential attack by new strains of CMD in Nigeria, which can combine to form a more destructive strain of the virus. IITA, therefore, took immediate preventative action to avoid a repetition of the devastation that occurred in Uganda during the 1990s. Since the launching of this mega-project, IITA has been producing thousands of new, disease-resistant, cassava plantlets and cuttings and delivers them to Nigerian farmers. The improved plants will not only resist the disease but will also slow its spread to non-resistant cultivars, acting as a barrier to the advance of CMD. IITA-bred cultivars also produce more cassava per plant and their distribution should lead to increases in total Nigerian production. As part of the unique preemptive strategy, IITA and its partners from both the Nigerian public and private sectors are working to establish value-added industries and post-harvest processing to ensure markets for the increased production that is expected. Hence, this Nigerian Presidential Cassava Initiative, which in 2003 brought the strong funding commitment of a Global Development Alliance between the largest oil company in the country and the major aid investor of the CGIAR, improves technology transfer to address CMD and to develop cassava processing that will provide greater incomes to farmers in 11 states, mostly in the southern “cassava belt”. It will also help identify further commercial markets for cassava, such as ethanol production, livestock feed and use in baking. In addition to being a staple food, starch from cassava is already used in other industries including textile manufacturing. Similarly and encouraged by IITA research impacts on the crop, the *Integrated Action Program for Cassava Starch Production and Export* was launched by the President of the Republic of Ghana for developing the cassava starch industry in this country as a major vehicle for job creation and poverty reduction in rural areas.

Impacts

Maredia and Raitzer (2006) indicate that the largest development impact of the Consultative Group on International

Agricultural Research (CGIAR) in sub-Saharan Africa came via support of long-term crop improvement and integrated pest management research dealing with biological risks. Indeed, research to increase yields in a broad range of agro-ecological zones and cultivation systems, to suit a wide variety of consumer preference, was launched by IITA through the deployment of bred-cassava cultivars in many African locations. There were about 206 releases of cassava cultivars in 20 African nations. In the 1990s African programs incorporated IITA bred-materials in 80% of their cassava bred-germplasm that led to 50% gains in cassava yields on average (Manyong et al. 1999). Such cassava cultivars represent an important contribution to Africa's food security, especially among the poor (Nweke et al. 2002) because the improved cultivars raised per capita output by 10% continent-wide, benefiting 14 million farmers. For example, the total benefits from the cassava multiplication partnership project between the National Agriculture Research Organization (NARO, Uganda) and IITA to combat the cassava mosaic disease pandemic in six districts was approximately US \$ 36 million over 4 years (1998-2001) for an initial investment of US \$ 0.8 million (Dixon et al. 2003). The success of cassava genetic enhancement in sub-Saharan Africa points out the benefits of having an eco-regional center such as IITA doing crop breeding solely, and together with many continental partners delivering the new seeds that impact on African livelihoods (Ortiz and Hartmann 2003). Clearly, there are some circumstances where national programs are already sufficiently developed to fulfill this role. In such cases (and the list will hopefully be rapidly expanding), international centers have a duty to rapidly devolve these activities to the national partners through technology and skills exchange (Ortiz and Crouch 2006).

The spectacular biocontrol of the cassava mealybug yielded economic returns of 200:1, with minimum benefits of US \$ 2.2 billion from a total expenditure of US \$ 14.8 million (Norgaard 1988, Zeddies et al. 2000). One could easily surmise that, without biological control, the mealybug would have destroyed most of the cassava grown across Africa. This project was unique in its geographic scale, organization and level of documentation, and has become a classic textbook example (Neuenschwander 2004). Likewise, in West Africa alone, where cassava green mite biological control was first achieved, economic benefits have reached a hundred fold –US \$ 100 in return for each US \$ 1 invested in the program (Dixon et al. 2003). It was not surprising therefore that the most recent impact report to the CGIAR Science Council indicates that about 80% of the US \$ 17 billion estimated impact of the CGIAR in sub-Saharan Africa result from the biological control of pests by IITA and national partners across the region (Maredia and Raitzer 2006). This is a truly awesome success and as such it is appropriate that one asks the question “*what factors and players were important for the agenda and priority setting process that led to this long-term endeavor*” (Ortiz and Crouch 2006). Not surprisingly the answer is complex, since a broad range of actors can be acknowledged: scientists who were on target with their ideas and translating them into research undertakings, stakeholders and clients who guided their priority setting, managers who supported the scientists and sought the resources for implementing their research, and donors who were convinced by the arguments from managers and scientists and were then willing to invest in this research-for-development agenda that relies on producing locally, minimizing risks and creating wealth in sub-Saharan Africa.

References

- Dixon AGO, Bandyopadhyay R, Coyne D, Ferguson M, Ferris RSB, Hanna R, Hughes J, Ingelbrecht I, Legg J, Mahungu M, Manyong V, Mowbray D, Neuenschwander P, Whyte J, Hartmann P, Ortiz R (2003). Cassava: from poor farmer's crop to pacesetter of African rural development. *Chronica Horticulturae* **43** (4), 8-15.
- Hahn SK, Isoba JCG, Ikotun T (1989) Resistance breeding in root and tuber crops at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. *Crop Protection* **8**, 147-168.
- Hahn SK, Terry ER, Leuschner K (1980a) Breeding cassava for resistance to cassava mosaic disease. *Euphytica* **29**, 673-683.
- Hahn SK, Howland AK, Terry ER (1980b) Correlated resistance of cassava to mosaic and bacterial blight diseases. *Euphytica* **29**, 305-311.
- Hahn SK, Terry ER, Leuschner K, Akobundu IO, Okali C, Lal R (1979) Cassava improvement in Africa. *Field Crops Research* **2**, 193-226.
- Hartmann P (2004) An Approach to Hunger and Poverty Reduction for Sub-Saharan Africa. International Institute of Tropical Agriculture, Ibadan, Nigeria.
- Herren HR, Neuenschwander P (1991) Biological control of cassava pests in Africa. *Annual Review of Entomology* **36**, 257–283.
- IITA (1992) *Sustainable Food Production in sub-Saharan Africa*. 1. IITA's contribution. IITA, Ibadan, Nigeria.
- Jennings DL, Iglesias C (2002) Breeding for crop improvement. In Hillocks RJ, Thresh JM, Bellotti AC (eds) *Cassava: biology, production and utilization*. CABI Publishing, Wallingford, Oxon, UK. Pp. 149-166.
- Jones WO (1959) *Manioc in Africa*. Stanford University Press, Stanford, CA, USA.
- Lancaster PA, Brookes JE (1983) Cassava leaves as human food. *Economic Botany* **37**, 331-348.
- Manyong VM, Dixon AGOD, Makinde KO, Bokanga M, WHYTE J (2000). *The contribution of IITA-improved cassava to food security in sub-Saharan Africa: an impact study*. International Institute of Tropical Agriculture, Ibadan, Nigeria.
- Maredia MK, Raitzer DA (2006) *CGIAR and NARS Partners Research in Africa: Evidence of Impact to Date*.
<http://www.sciencecouncil.cgiar.org/meetings/meeting/SC5/SPIA%20Africa%20IA%20study.pdf>
- Mégevand B, Yaninek, JS, Freese DD (1987). Classical biological control of cassava green mite. *Insect Science and Its Application* **8**, 871–874.
- Nassar NMA, Ortiz R (2006) Cassava improvement: challenges and successes. *Journal Agricultural Science* (Cambridge). In press.
- Neuenschwander P (2001) Biological control of the cassava mealybug in Africa: a review. *Biological Control* **21**, 214–229
- Neuenschwander P (2004) Harnessing nature in Africa: biological pest control can benefit the pocket, health and the environment. *Nature* **432**, 801–802.

Norgaard RB (1988) The biological control of cassava mealybug in Africa. *American Journal of Agricultural Economics* **72**, 366–371.

Nweke FI, Spencer DSC, Lynam JK (2002) *The Cassava Transformation: Africa's Best-kept Secret*. East Lansing: Michigan State University Press.

Ortiz R (2004a) *IITA 40 years after*. Board of Trustees Docket. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Ortiz R (2004b) Breeding clones. In Goodman RM (ed) *Encyclopedia of Plant & Crop Science*. Marcel Dekker, Inc., New York. Pp. 174-178.

Ortiz R, Crouch JH (2006) Creating an effective process to define, approve and review the research agenda. In Loebenstein G, Thottappilly G, Lawson R (eds) *Agricultural Research Management*. Springer, Germany. In press.

Ortiz R, Dochez C, Moonan F, Asiedu RA (2006) Breeding vegetatively propagated crops. In Lamkey K, Lee M (eds) *Plant Breeding*. Blackwell Publishing, Ames, Iowa. Pp. 251-268.

Ortiz R, Hartmann P (2003) Beyond crop technology: The challenge for African rural development. In *Vol. 2 Reference Material of the Sub-Saharan Africa Challenge Program "Building Livelihoods through Integrated Agricultural Research for Development – Securing the Future for Africa's Children"*. Forum for Agricultural Research in Africa (FARA), Accra, Ghana. Pp. 39-72.

Robinson, R.A. (1995) *Return to Resistance: Breeding Crops to Reduce Pesticide Dependence*. International Development Research Center, Ottawa, Ontario, Canada – agAccess, Davis, California, USA.

Yaninek JS, Herren HR (1988) Introduction and spread of the cassava green mite *Mononychellus tanajoa* (Bondar) (Acari: Tetranychidae), an exotic pest in Africa, and the search for appropriate control methods: a review. *Bulletin of Entomological Research* **78**, 1-13.

Zeddies J, Schaab RP, Neuenschwander P, Herren HR (2000) Economics of biological control of cassava mealybug in Africa. *Agricultural Economics* **24**, 209–219.

Source population (up to 100 000 seedlings) after crossing selected parents

↓ Defect elimination or mild-selection for specific attributes (e.g. CBB or CMD)

Single plots of (about 3 000 selected clones) for clonal evaluation

↓ Screening for specific attributes as per breeding plan

Preliminary yield trial (likely 100 clones) with 2 replications

↓ Screening to confirm attributes and early yield assessment

Advanced yield trial (a maximum of 25 clones) with 3 to 4 replications in at least 3 locations

↓ Further yield assessment

Uniform yield trial (10 best clones) with 4 replications in many locations

↓ Yield assessment and testing stability across location range

On farm participatory testing of elite materials (2 – 5 clones)

↓ Farmer (and sometimes end-users') testing

Multiplication of selected clone(s) and cultivar release

(through appropriate national committee)

Fig. 1. Conventional breeding scheme for cassava

Sources: Jennings and Iglesias (2002), Ortiz (2004b)

CBB = cassava bacterial blight, CMD = cassava mosaic disease