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INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

ANNUAL REPORT 1994

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for specific food crops, and with ecological and regional responsibilities to develop sustainable production systems in Africa. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA is governed by an international board of trustees and is staffed by approximately 150 scientists and other professionals from about 40 countries and 1,500 support staff. Most of the staff are located at the Ibadan campus, while others are at stations and work sites in other parts of Nigeria and in the countries of Benin, Cameroon, Côte d'Ivoire, Ghana, Malawi, Mozambique, Tanzania, Uganda, and Zambia. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional and national programs in many parts of sub-Saharan Africa. The research agenda addresses crop improvement, plant health, and resource and crop management within a farming systems framework. Research focuses on smallholder cropping systems in the humid and subhumid tropics of Africa and on the following major food crops: cassava, maize, plantain and banana, yam, cowpea, and soybean.

The goal of IITA's research and training mission is to improve the nutritional status and well-being of low-income people of the humid and subhumid tropics of sub-Saharan Africa.

Global links. Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP), the CGIAR is an informal association of over 40 governments, international organizations, and private foundations. The CGIAR provides the main financial support for IITA and 17 other international centers around the world, whose collective goal is to improve the quantity and quality of food production in developing countries.

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ABBREVIATIONS USED IN THE TEXT INSIDE BACK COVER

Director General's Report

The Year in Perspective

MOYO BOGARIN

Lukas Brader, Director General, in an IITA yam research plot

Agriculture is the foremost component of the economy in sub-Saharan Africa, as with other developing regions. It has a crucial role to play in self-sustaining, balanced development of the economy, which can happen only when people across all sectors have adequate food and skills to enable them to do meaningful work.

Sub-Saharan Africa is the only region in the world where the population increases faster than food production. The region's current 2% rate of annual growth in food production, as against the 3% annual growth in population, stems from a 30-year decline in per capita food production.

At a 4% annual growth rate, however, food production would be sufficient by the year 2000 to feed all the region's peoples. That level of production could also provide work and stimulate other sectors of the economy. But it must be based on resource-conserving technologies, if it is to be sustainable.

IITA is committed to advancing sustainable agricultural development in the region through research and related activities, together with national and international collaborators. We have developed high-yielding crops and ecologically sound technologies to sustain soil fertility and protect those crops. Signs that we are working in the right direction have come from many sources, including our success in winning the biennial King Baudouin Award, most recently in 1994 for our plantain research.

"Millions of small African farmers and their families, for whom plantains are a nutritious and tasty basic food, will benefit from IITA's advances," said Ismail Serageldin, chairman of the Consultative Group on International Agricultural Research (CGIAR), who presented the award in Washington, DC, on 24 October 1994. "This is truly a milestone contribution toward stemming the long-term decline of per capita food production in sub-Saharan Africa."

The Technical Advisory Committee to our global system of 16 CGIAR centers gives the King Baudouin Award every 2 years to the center which has produced work with the most promising potential for impact. IITA has won that award 3 of the 7 times that it has been granted:

- In 1986, for the development of maize resistant to the maize streak virus, the cause of one of the most economically damaging crop diseases in sub-Saharan Africa.

• In 1990, jointly with the Centro Internacional de Agricultura Tropical (CIAT), for the biological control of the cassava mealybug in tropical Africa, which threatened to devastate cassava crops across the continent with its rapid spread.
• In 1994, for the development of hybrid plantain resistant to black sigatoka, a fungus which causes a disease that threatens plantain crops worldwide; and for advances in *Musa* genetics which can facilitate breeding of new varieties to counter other production constraints.

All three awards have recognized work which reflects an ecologically sound crop-management strategy that minimizes the need for pesticides, and enhances sustainability in food crop production in an area of the world that requires it urgently.

MOYO BOKARI

Our research on the airborne black sigatoka fungus (at right: spore trap) will prevent devastation of plantain crops; while our research into processing of plantain and cooking-banana foods has generated new interest (below) in their commodity potential.

EDUN NWUDU

IITA also made important progress in other areas during 1994 toward the goal it shares with its partners in sub-Saharan Africa—to improve the nutrition and well-being of low-income people through agricultural research.

Crop improvement IITA's breeders advanced work on crops other than plantain. Collaborative research with national programs carried many high-yielding, improved varieties of cassava, cowpea, and soybean close to the stage of release to farmers. Registration of new plaintain and maize varieties put them into the public domain.

Breeding of maize for resistance to the parasitic plant *Striga hermonthica*, and to the stem and ear borer *Eldana saccharina*, made substantial progress.

Cowpea work also showed excellent progress, in improving farmers' local varieties by introducing resistance to important pests, diseases, and parasitic plants. Nonconventional approaches to cowpea breeding, involving biotechnology and wide crossing to find and incorporate resistance to postflowering insect pests, got well under way.

New ground in biotechnology was broken for sub-Saharan Africa. Close cooperation with the Nigerian government yielded biosafety guidelines for the country that mark a dramatic first for the region. Following a year-long consultative process in which the guidelines were drafted and developed jointly, we held a workshop in January

1995 on the implementation of the biosafety guidelines, which was attended by senior staff and heads of relevant departments and research institutions in Nigeria. Critical support came from the Stockholm Environment Institute and the Biotechnology Advisory Commission.

Plant health During 1994, we continued to advance crop protection programs with ecologically sound practices. Our project in West Africa with the United Nations Development Programme (UNDP), Ecologically Sustainable Cassava Plant Protection (ESCaPP), finished its diagnosis of plant protection problems. The results of surveys made with scientists from Cameroon and Nigeria and international specialists are the basis for activities of researchers, extension workers, and farmers in the next few years which will promote environmentally sustainable practices.

An ecologically based strategy in biological control of the cassava green mite brought successful establishment and spread of two predatory mites from Brazil: *Typhlodromalus aripo*, in 8 sub-Saharan countries over an estimated 1,500 square kilometers, and *T. manihoti*, in 2 of those countries over an estimated 100 square kilometers.

In maize, our scientists confirmed the seedborne nature of downy mildew disease, caused by the fungus *Peronosclerospora sorghi*. We can now refine our strategy to control the spread of the disease, which causes considerable damage in the region.

BENSON TADARE

MOYO BOLARIN

Grasshoppers (above) and locusts can lay waste to cultivated fields. Our sustainable solution is to use spores of the fungus *M. flavoviride* (in solution, at left) in a biopesticide that, in 1994, showed its efficacy in Mali.

With our general mandate for sustainable agriculture, we cannot confine integrated pest management research to mandate crops alone. Pest problems need to be considered in their entirety. We have thus pursued a novel strategy to control the most serious grasshopper pest in the humid forest zone of Africa, the "elegant" grasshopper (*Zonocerus variegatus*).

In 1994 we greatly enhanced our ability to produce spores of the fungus *Metarhizium flavoviride*, which has demonstrated effective control of the grasshopper. Our yields of spores per kilogram of substrate were increased fivefold and mass production tenfold; both of those developments considerably reduce production costs. We improved storage methods of dry spores under ambient conditions.

Experiments and modeling quantified the grasshopper mortality caused by spore residue in the field. Results suggest that spore applications may not be needed every year. The effectiveness of this fungus in controlling the grasshopper under field conditions was demonstrated for the first time in Mali, in cooperation with national program scientists.

Resource and crop management Sustainable production systems require that natural resources receive adequate attention in efforts to improve the productivity and management of crops. IITA scientists have over the years studied how soils become degraded, especially through changes in the soil organic matter content, and how vegetation management can help restore fertility. The aim is to enable farmers to maintain soil productivity through organic processes that replenish soil nutrients and reduce dependence on commercial fertilizers.

During 1994, research in soil productivity included studies of nitrogen-use efficiency in alley cropping, as well as competition for nutrients between trees in the hedgerows and crops in the alleys. While the nitrogen contribution of the trees was high (120–250 kilograms per hectare each year), the nitrogen actually used by the associated crop was low. The findings suggest that improvement of the management system—in terms of the timing and methods of applying the prunings—is an issue which deserves our attention.

In a fallow management study in the forest/savanna transition zone, herbaceous legumes fared better than trees in improving soil physical conditions. That finding reinforces interest in those leguminous cover crops for fallowing purposes. Progress was made in selecting legumes (woody, herbaceous, and grain-yielding) that effectively utilize soil mycorrhizae. Such legumes would consequently use phosphorus efficiently and could tolerate soils with a low phosphorus content.

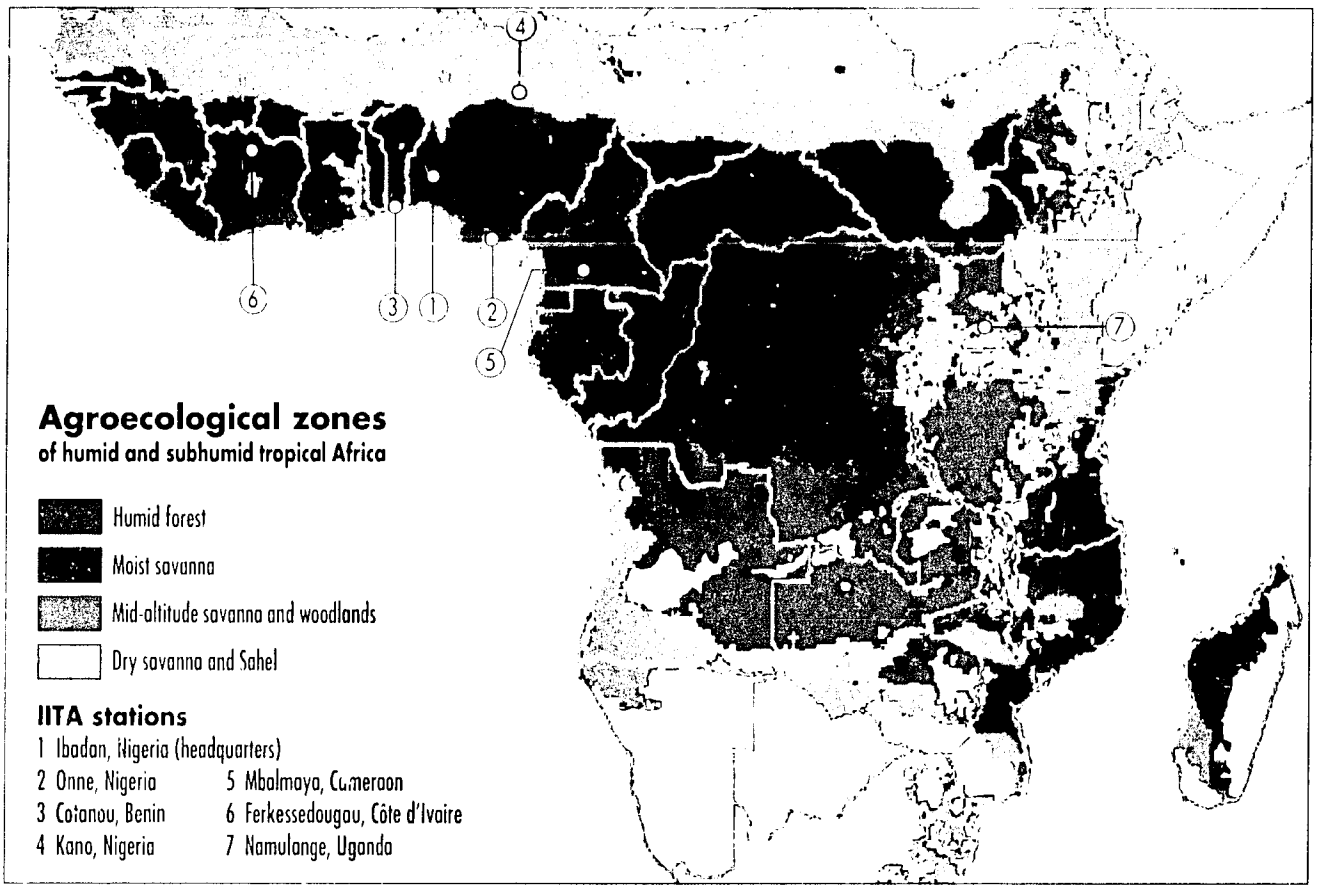
Studies of the dynamics of soil organic matter continued to focus on how plant residues, as they decompose, contribute to nutrient uptake by growing crops. Because farmers remove aboveground plant residues for use as fodder and fuelwood, the root residues serve as the main source of new nutrients in soil organic matter. Roots are known to store considerable quantities of plant nutrients.

A recent study at IITA found that roots with a high nitrogen content and low carbon-to-nitrogen ratio make a good nitrogenous fertilizer. A selection of roots of agroforestry tree species was "incubated" for two months in the subsoil. The effect on a maize crop planted in the same field was like that of a natural fertilizer, in improving biomass yield as well as uptake of nitrogen, phosphorus, potassium, calcium, and magnesium by the maize. The information from this study deepens available knowledge in this area.

The Collaborative Study of Cassava in Africa (COSCA) continued analysis of the data it has

Judicious use of trees and herbaceous legumes helps farmers to replenish spent soils and increase food production. The IITA/ICRAF nursery at our High Rainfall Station at Cane, shown here, provides multipurpose trees for collaborative research needs.

EDUI NWULU



amassed on factors affecting cassava production and consumption across the continent. Critical information has emerged about attributes farmers want in their cassava varieties, as well as the dynamics of the cassava economy. These results can increase the usefulness of our work in cassava improvement and utilization.

Equipment was designed at IITA over the past few years to improve utilization of crops—including chippers, crushers, grinders, polishers, shellers, and stoves. The results of this highly practical line of research were disseminated through training in 1994 to farm communities and consumer groups, such as nongovernmental organizations and small businesses, which can manufacture the equipment locally. The benefits from different applications of the equipment were analyzed to guide further development.

Training courses created capability in use of geographic information systems in 14 countries of sub-Saharan Africa, while remote sensing techniques were applied by IITA scientists working with national scientists to complete characterization and ground-verification of inland valleys in 6 countries.

The Alley Farming Network for Tropical Africa (AFNETA) and the Soil and Plant Analytical Laboratories Network of Africa (SPALNA) were both very active in training and in dissemination of skills and information critically needed in African agricultural research.

Global concerns Global concern about environmental conservation at the 1992 "Earth Summit" prompted the CGIAR to reorganize the research programs of its centers along the lines of agroecological zones or regions ("ecoregions"). IITA started evolving an ecoregional program for the humid and subhumid tropics of sub-Saharan Africa, to include all interested national programs and CGIAR centers. [See map of Africa's agroecological zones, above.]

IITA recast its program activities into 23 ecoregional projects, which will begin operating in 1995. While projects are ecoregionally conceived, IITA will retain its discipline-based divisional structure for the time being, to sustain professional perspectives.

On the budgetary side, the year began for IITA with the prospect of a severe financial crisis, caused by donor reductions in the funding which supports all CGIAR centers. Closer to home, our host government Nigeria introduced a fixed exchange rate for its currency, the naira. These pressures were partly alleviated by the devaluation of the CFA franc (which helped reduce the cost of IITA's operations in the francophone countries of West Africa), and by systemwide measures taken by the CGIAR.

Nevertheless, the crisis called for severe tactics, including elimination of some staff positions and postponement of some recruitment, with adverse consequences to the flow of our work. We can all be happy that the year ended on a brighter note in this respect, owing to additional grants and other income, than had earlier been anticipated.

The CGIAR-wide budgetary problems of 1994 are part of a global phenomenon of inadequate support for agricultural development. Reduced funding for research in recent years has already borne serious consequences. The weakness of national research institutions in sub-Saharan Africa inhibits the effectiveness of research efforts. That weakness stems directly from lack of governmental support to the critical agricultural component of national economies.

Developed countries support their agricultural research—and manifestly benefit from the results—to a much greater degree than do developing countries. In developed countries as a whole, agricultural research expenditures represented 2.01% of agricultural GDP for the period 1980–1985. For sub-Saharan countries, the economies of which depend so heavily on agriculture, that percentage was 0.54 for the same period.

The experience of developed countries shows how agricultural research can improve economic development—but only when research systems are well organized and adequately supported. If the global challenge to double food production by the year 2020 is to be met, donor and recipient governments alike must play their part with policies that encourage agricultural activities, and with facilities and infrastructure to support them.

The farmers themselves have shown they are willing to take risks in adopting new technologies to increase their productivity, when conditions appear to support success. It is up to the rest of us involved to provide the right technologies and economic environment for them to succeed.

BENSON FADARE

Farmers bear the burden of risks; it is up to us to provide them with the means to succeed.

Highlights 1994

New crop varieties from IITA were released by agricultural authorities in 7 African and 1 Latin American country during 1994, for extension to farmers.

CASSAVA Uganda officially released 3 elite, IITA-improved cassava clones. One of IITA's first and most widely adaptable, improved clones, TMS 30572, was named "Migyera", after the town where the cassava program has a testing site. TMS 60142 was dubbed "Nase 1", an abbreviation of "Namulonge selected". (Namulonge is the location of the National Agricultural and Animal Production Research Institute [NAARI] which evaluated the clones.) TMS 30337 became "Nase 2".

Nase 1 is an example of how an interaction between genotype and environment can make a critical difference in the productivity of a particular clone. TMS 60142 shows a fairly poor yield in the West African lowlands. But, in Uganda, a country of higher altitudes, breeders found it performed much better and selected it for their program because of its stable yield and desirable food quality, as a mealy, "boil-and-eat" type.

SOYBEAN Uganda released "Nam 2" (again named to indicate NAARI selection), a soybean variety developed from an advanced breeding line from IITA. In Cameroon, the national extension authorities recommended 5 IITA varieties in a pamphlet for smallholder cultivation. (IITA has no record of their formal release.) In Nigeria, the nationally coordinated research project on soybean submitted 2 IITA varieties to the official release committee for their consideration.

COWPEA Nigeria announced releases of 5 IITA varieties, including 2 which are improved versions of local varieties popular with farmers. Sierra Leone released 3 IITA varieties. Five countries announced large-scale testing and seed multiplication of IITA-improved varieties: Cameroon (2 varieties), Côte d'Ivoire (1), Mauritania (3), Niger (1), and—in Latin America—Paraguay (3).

Registrations of IITA germplasm were published in international scientific journals during 1994.

MAIZE Breeding materials developed in Cameroon by IITA and the national agronomic research institute, IRA, were registered in the public domain by publication in the journal *Crop Science*: 18 first-cycle and 19 second-cycle tropical, midaltitude, inbred maize germplasm lines (published in *Crop Science* 34:1422, 1994 and 34:1419–1420, 1994; respectively). Cameroon had released them in 1991 for national use as source germplasm or as parental lines for hybrids for the high-rainfall tropical midaltitudes.

Four tropical midaltitude maize populations, suitable as cultivars and as source germplasm for further development, were also registered by publication in *Crop Science* (34:1420–1421, 1994). These open-pollinated populations, as well as the inbred lines, were jointly developed by IITA and IRA as part of the USAID-supported NCRE project (described in "A Project Postscript", page 44). Both the inbred lines and populations are among the few internationally available that have been developed for the high-rainfall, tropical midaltitudes of West and Central Africa.

PLANTAIN (See "New *Musa* from Africa" after these highlights.) The journal *HortScience* accepted the registration of 14 improved, plantain-derived diploid cultivars and PITA-9, a plantain hybrid derived from the False Horn gene pool through somaclonal variation. Published in 1995 (*HortScience* 30.1:147–149), the new materials can be utilized in germplasm enhancement and genetic research on *Musa*.

Firsts

The steering committee of the East and Southern Africa Regional Center (ESARC) held its inaugural meeting in March in Kampala, Uganda. With participants from 8 countries of the region, the committee developed research priorities for the center's banana/plantain and cassava improvement program.

Following a capital investment phase in 1993 that included development of its Sendusu Research Farm at Namulonge near Kampala, ESARC organized its research program during 1994. The IITA team at ESARC expanded to 5 scientists.

The first cycle of harvesting of IITA and FHIA *Musa* hybrids in multilocational trials, which ESARC coordinates, started in 5 countries: Burundi, Kenya, Malawi, Uganda, and Zanzibar.

For full spellings of abbreviated names, see inside of back cover.

A cassava seedling nursery with a total of 120,000 seeds from 25 families was established during the first and second season of 1994. The first group training course on banana research and technology transfer was organized by IITA and ESARC's host, the National Agriculture Research Organisation (NARO) of Uganda, in Kampala during June/July. For training in graduate research, ESARC hosted 5 PhD and 1 MSc student from Uganda and Tanzania in banana research, and 3 MSc students from Belgium, Netherlands, and Germany in banana nematology.

An evaluation of the first three years (1992–1994) of the Regional Research Program for Maize and Cassava, supported by France and the CGIAR, found that the project had contributed significantly toward national research goals.

The knowledge base in cassava and maize increased in the following fields (in countries identified in parentheses):

- varietal improvement for adaptation to local needs (Togo, Guinea, Cameroon)
- agronomy of cropping systems which include maize, cassava, and legumes (Benin)
- postharvest research activities (Cameroon, Gabon, Togo)
- collection and evaluation of local cassava germplasm, compared with varieties from IITA (Nigeria, Cameroon, Gabon, Congo, Benin, Togo, Guinea)

On-farm adaptive research for cassava, maize, rice, cowpea, and soybean was approved in 1994 by the European Union for a second phase of project funding in 21 countries of West and Central Africa.

Improved cassava and sweet potato planting materials have been multiplied and distributed in Malawi, as a drought-recovery measure since 1992, through the joint efforts of Malawi's national root crops program, regional root-crop research networks, FAO, UNICEF, several NGOs, and farmers, with USAID assistance. IITA contributed germplasm as well as technical and training support to collaborators.

The project was evaluated during 1994. Cassava was found to have been established on about 91 hectares in primary and secondary multiplication nurseries, while sweet potato had been established on 34 hectares. Some of the material, especially sweet potato, had been supplied to some 17,500 farm families.

That achievement within two seasons is remarkable, considering the biological cycles of cassava (9–12 months) and sweet potato (5 months) which must be completed before the materials are ready for transplanting. (The projection for the 1995 rainy season was cassava in 2,000 hectares for 9,000 families, while sweet potato material would be sufficient for 3,500 hectares and 350,000 farm families.)

A broad range of cassava and sweet potato research started or continued, in different parts of Southern Africa, as the Southern Africa Root Crops Research Network (SARRNET) became operational with key scientists at its coordinating center at Lilongwe, Malawi, and in Mozambique, Tanzania, and Zambia. SARRNET, with USAID and IDRC funding and technical support from IITA and CIP, aims chiefly at germplasm enhancement and population improvement, especially for the midaltitudes ecologies; development of technologies for improved plant health and postharvest utilization of cassava; and development of systems to expedite distribution of the improved planting materials to local extension services and, ultimately, farmers.

Cassava research results of the East Africa Root Crops Research Network (EARRNET), with the long-term goals of improving food security and increasing famers' income in East Africa, were evaluated by the donor USAID. Methodologies for developing improved varieties, including seed and planting materials, were found to be well established. National programs were routinely generating improved varieties in response to needs, and readily exchanging germplasm and research information. Capability in applying biological control and identifying diseases was found to be generally high. On-farm and farmer-participatory research were gradually expanding and slowly providing adoption and impact indicators. Socioeconomic studies were being completed and benchmark database publications were expected.

Seeds of Hope, a project to restore planting materials of essential food crops to the devastated farms of war-torn Rwanda, was launched by CGIAR centers. EARRNET assisted in multiplying and distributing cassava varieties from Uganda adapted to ecologies in areas which border Rwanda. SARRNET did the same from Tanzania.

Heads of national maize programs in West and Central Africa, at the first meeting of the West and Central Africa Maize Network (WECAMAN), elected a steering committee which approved the network's action plan for the next two years. An ad hoc research committee was appointed to review the 37 collaborative proposals from all member countries and to allocate research funds of $80,700 for the 1994 cropping season.

Research at the network's coordination center included breeding for early maturity and resistance or tolerance for drought, streak virus,

For full spellings of abbreviated names, see inside of back cover.

Deep roots, many branches, should make a stable savanna intercrop

Drought, together with competition from cereals in intercropping systems, depress yields from cowpea in the dry (Sudan) savanna. IITA, with technical and funding support since 1990 from the Japan International Research Center for Agricultural Sciences (JIRCAS), has been developing improved cowpea varieties with drought tolerance and greater suitability for intercropping with cereals. The work is taking place mainly at the Kano Station, in Nigeria's dry savanna where the cowpea grain is an important source of dietary protein for people and the stems and leaves are fodder for livestock.

The cowpea appears to rely on two strategies in adapting to dry growing conditions. One is prevention of water loss, through closure of the stomata or pores of the leaf surface. The IITA/JIRCAS team first tested this capacity by screening 900 cowpea lines for drought tolerance at seedling stage, during the 1990/91 dry season. By 1994 several lines had been selected which consistently gave good grain yields and biomass, when grown under conditions of low moisture.

The researchers thereupon compared the root characteristics of drought-tolerant cowpea lines with those of drought-susceptible lines, as a test of the plant's reliance on a second strategy to survive drought: to take advantage of greater moisture availability deeper down in the soil, by means of a well-branched root system. The drought-tolerant cowpeas indeed had better root development, in terms of long and numerous branches, at greater soil depths than had the drought-susceptible lines.

Among the best is the cowpea germplasm line TVu 11979 (pictured here in comparison with a drought-susceptible line), which shows both drought tolerance at seedling stage and root development at later stages.

Farmers in the dry savanna traditionally intercrop their cereals and cowpeas, thereby optimizing their returns from land and labor resources in the short growing season with erratic rainfall. The nature of the cereal/cowpea competition and its effects on cowpea growth and yield were investigated. Yield of cowpea grain was greatly reduced when a cowpea intercrop was planted 3 weeks after a millet crop, compared with cowpea planted simultaneously with the millet.

Besides time of planting, the number of leafy branches that the plant developed was significantly related with grain yield. Cowpea intercropped with millet simultaneously, or planted as a sole crop, developed 4 branches per plant, on average; while cowpea sown 3 weeks after the millet bore between 0.5 and 2 branches each. Evidently, shading during the cowpea's early growth stages limits branching, and ultimately yield.

IITA and JIRCAS are currently working to combine selection of drought-tolerant, deeply rooting cowpea lines with good grain and fodder yields, and other desirable characteristics, in local intercropping systems with cereals.

T. TERAO

T. TERAO

Leafy branches proclaim the high drought tolerance of cowpea germplasm line TVu 11979 (top), in comparison with a susceptible line in the same field that has practically succumbed to drought.

Counterattack on two fronts

For 20 years an enemy of cassava in Africa, the cassava green mite now faces formidable barriers in continuing its depredations, because of advances in biological control and host plant resistance.

MOYO BOLARIN

Unblemished, dark green leaves affirm resistance to the cassava green mite of the IITA cassava variety on the right side. Leaves of the susceptible variety are mottled and the growing tips deformed.

BIOCONTROL IITA biological control research has identified and established several predators of the pest in cassava-growing areas across Africa. Surveys during 1994 which followed up earlier releases confirmed the survival of two mite species of the genus *Typhlodromalus* in West Africa and one *Neoseiulus* species in East and Southern Africa. *T. manihoti* was found in Ghana 4½ years after its initial release. Astonishingly, *T. aripo* covered an estimated 1,500 square kilometers after only 11 months. (See "Tide of battle turns against the major mite pest", page 42.) In East Africa, *N. idaeus* was found in Kenya 2½ years after first release and in Zambia, not far from the Zairean border, nearly 1 year after release. Predators from past releases elsewhere are expecied to have survived and to add to these successes when confirmed.

HOST PLANT RESISTANCE IITA breeders achieved a long-term breeding objective in 1994: cassava genotypes which combine resistance to cassava green mite with other desired traits, such as appropriate agronomic and food qualities. The results of extensive multilocational testing showed high levels of resistance. Improved, high-yielding genotypes with this resistance, and their seed progenies, were distributed to 18 national programs in sub-Saharan Africa during the year.

The mechanisms of resistance appear to consist in:

- antibiosis (i.e., a part or product of the plant that deters the mite's growth and development)
- non-preference (lack of appeal to the mite)
- tolerance of the plant for the mites' depredations.

High density of the hair-like trichomes (on the leaf's lower surfaces and the growing tip of the plant), and greater length of trichomes, resulted in greater resistance of the cassava plant to damage from the mite. The ability of the plant to "stay green" or retain its canopy under dry conditions, an indicator of drought tolerance, also figured positively in relation with mite resistance.

Cassava leaves with a high calcium content and low phosphorus and starch content showed low levels of damage; perhaps indicating greater thickness of cell walls which could resist the mite. High levels of 5 amino acids (isoleucine, tyrosine, phenylalanine, glutamate, aspartate) in the leaves were also associated with reduced damage.

The research indicated that genes which control cassava green mite resistance are independent of genes for resistance to cassava diseases. Hence, genotypes can be selected for disease and mite resistance traits separately and crosses made between the cultivars for multiple pest resistance.

and *Striga*. In regional uniform variety trials in 17 countries, 34 early and 25 extra-early sets were dispatched. WECAMAN also organized a workshop on *Striga* control, a technicians' training course, and a monitoring tour of maize research in Mali and Côte d'Ivoire, as means to strengthen network members' capabilities.

Postharvest technology

IITA received new funding for postharvest research and favorable attention from promoters and consumers during the year.

SOYBEAN The IDRC-funded project on soybean processing and utilization in Nigeria (Phase II) was completed in 1994. IDRC agreed to fund a third phase, to be implemented in Ghana and Côte d'Ivoire.

ON EXHIBIT A surge of public interest in IITA postharvest technology brought the Institute invitations to exhibit at several trade fairs around Nigeria and the National Merit Award for Local Raw Materials Development, of the Raw Materials Research and Development Council of Nigeria, at their exhibition at Lagos during December. From followup contacts after such events and requests for information and advice on postharvest research and products, it is clear that IITA has evolved a holistic role for itself which encompasses field production, postharvest systems, and consumer issues.

Alley Farming Network for Tropical Africa

AFNETA held 4 regional alley farming workshops that discussed proposals for on-farm developmental research, in 6 West and East African countries with high adoption potential, and for experimental research on farm and on station elsewhere in Africa, to be supported by Canadian government funding. The large-scale developmental projects aim to reach 600,000 farmers within 5 years.

In recent experimental research, the most promising multipurpose tree species were selected for the semiarid zone (*Prosopis juliflora, Albizia lebbeck, Moringa oleifera, Leucaena leucocephala*, and *Prosopis chilensis*); and for the subhumid zone (*Senna siamea, Albizia lebbeck, Leucaena leucocephala, Gliricidia sepium*, and *Albizia lebbeck* Malindi). Earlier research had identified the best candidates for the humid forest zone and the midaltitudes (*Calliandra calothyrsus, Leucaena leucocephala*, and *Gliricidia sepium*).

Integrated Pest Management

In 1994, IITA was designated the convening center to steer the implementation of the global IPM initiative among all CGIAR centers. A technical coordination meeting in The Hague in February 1995 developed a definition and policy statement on IPM, established a secretariat in IITA's Plant Health Management Division, and discussed 8 pilot inter-center projects. The IPM initiative provides international agricultural research centers an opportunity to enlarge collaboration, such as IITA has done in biological control and host plant resistance, in addressing priorities on the agenda for action of the 1992 United Nations Conference on Environment and Development.

Research on IPM requires particular kinds of characterization studies to establish the importance of the various constraints, before research for implementation is undertaken and as a basis for the evaluation of impact. All research activities in diagnosis and IPM implementation have been consolidated into 6 projects from 1995. Four are crop-based (cassava, maize, grain legumes, banana and plantain), 1 focuses on a particularly difficult parasitic plant (*Striga*), and 1 concerns biological control. The following paragraphs highlight the main project activities of 1994.

IPM FOR CASSAVA (See panel story opposite.)

- Establishment and spread of predators of the cassava green mite (CGM), the mites *Typhlodromalus manihoti*, in 2 countries over approximately 100 square kilometers, and *T. aripo* in 8 African countries over some 1,500 square kilometers.
- Attainment of significant CGM resistance in combination with other desired characteristics in improved cassava varieties.
- Completion of regional diagnosis for setting priorities for cassava plant protection in ESCaPP countries. Project training curriculum developed.
- Characterization of 250 strains of *Xanthomonas campestris* (pathovar *manihotis*) from 5 countries—pathologically, physiologically, and genetically.

IPM FOR MAIZE The project encompasses field pests and postharvest problems within large projects on the larger grain borer and other stored-product pests.

- Seed-borne nature of downy mildew of maize, *Peronosclerospora sorghi*, in Nigeria was demonstrated. This discovery is key to development of strategies to control the spread of the disease.
- Data on aflatoxin in maize in the dry savanna of Benin showed a 50% increase in contamination of stored maize within 4 months from time of storage.
- Good progress was made in breeding for resistance against the stem borer *Eldana saccharina*.
- Evaluation of the role of grasses and rice as "trap" plants for stem borers indicated management op-

For full spellings of abbreviated names, see inside of back cover.

tions in reducing damage to maize.
• Success in rearing exotic parasitoids *Cotesia sesamiae* and *C. flavipes* on stem borer *Sesamia calamistis* reveals a promising new pest/parasitoid association.
• Postrelease studies of *Teretriosoma nigrescens*, a predator of the larger grain borer (*Prostephanus truncatus*) previously released by GTZ in Togo and dispersed into southwestern Benin, showed that the predator was spreading rapidly. Data from pheromone traps and traditional maize stores demonstrated impact on pest populations.

INTEGRATED *STRIGA* CONTROL Promising solutions in habitat—and particularly soil—management are explored in this multidisciplinary approach to control *Striga* species and other parasitic plants.
• About 130 chemical compounds from both hosts and non-hosts were found to be active in seed germination of *Striga* species. They were isolated and will be tested for use, ultimately, in rapid screening systems.
• The role of people in dissemination of seed of *Striga* species (in mixtures with crop seed) was clarified.
• Non-host screening technology was greatly simplified and became available to national programs.

Building on earlier progress and use of a standardized artificial field infestation technique, IITA maize breeders increased levels of resistance to the parasitic plant *Striga hermonthica*, in both hybrid and open-pollinated maize cultivars. Results from 1994 trials under *Striga* infestation show that grain yields of some open-pollinated cultivars (populations and synthetics) approached those of the most resistant hybrid in IITA's anti-*Striga* arsenal.

Besides their encouraging yields, the new maize cultivars showed improvement in the capacity to reduce emergence of *Striga* plants above ground. IITA has, since 1993, redoubled its efforts to select maize with this trait, in order to reduce the amount of *Striga* plants that flower and add their seed to the soil. The capacity to activate—or, conversely, to discourage—the germination process in *Striga* is controlled genetically.

IPM FOR LEGUMES From 1995, the special project *Protection écologiquement durable du niébé* (PEDUNE) will become part of the larger IITA project on IPM for legumes.
• Isolates of *Bacillus thuringiensis* from Auburn University were highly effective in killing first instars of the pod borer *Maruca*.
• Parasitoids of *Megalurothrips* spp. from Malaysia were taken to Wageningen Agricultural University for quarantine testing. First offspring on *M. sjostedti* showed promise for usefulness of this new association.
• Sclerotia of *Dactuliochaeta glycines* were detected on soybean seed obtained from pods intected with red leaf blotch, indicating a potential for seed transmission.

IPM FOR *MUSA* Parallel activities are being conducted in the East African highlands on banana, under the East and Southern Africa Regional Center (ESARC), and in lowland West Africa on plantain.
• Completion of characterization surveys on banana in Uganda enhanced understanding of pest distribution and damage severity.
• Sigatoka/plant interactions suggested that research on stations should move to farmers' fields, preferably in "benchmark" sites.
• Fungal pathogens effective against banana weevil were identified in laboratory studies and were tested for field-persistence and possible delivery systems.

Biocontrol

Biological control is achieved either through introduction of beneficials against pests in the farming system, or through application of indigenous fungi, as tested against locusts and grasshoppers. The latter project, in collaboration with many institutions, will soon be expanded to most of Africa.

All biological control activities against the cassava green mite and the cassava mealybug have been combined with the project on Ecologically Sustainable Cassava Plant Protection (ESCaPP) and other smaller special projects and are reported under IPM.
• For the first time, control of Sahelian grasshoppers by the fungus *Metarhizium flavoride* was demonstrated in Mali.
• Mass production rate of the fungus *M. flavoviride* was increased tenfold. Yield of *M. flavoviride* spores per kilogram of substrate was increased fivefold. Consequently, costs of formulated spores plummeted from $40 to less than $8 per hectare. Storage of dry spores was improved so that spores remain viable for several months.
• Experiments and subsequent modelling demonstrated impact of spore residue (i.e., pest mortality) in the field. Consequently, spore applications may not be needed every year.
• The parasitoid *Anagyrus mangicola* was finally established among the last high mango mealybug infestations in Benin, namely those in big towns, particularly in the north. That parasitoid has increased the impact of the previously established, coexisting *Gyranusoidea tebygi*.
• Two serendipitously introduced parasitoids of the spiralling whitefly, *Encarsia ?haitiensis* and *E. guadeloupae*, were found to have improved whitefly control after having spread throughout Benin.

For full spellings of abbreviated names, see inside of back cover.

Gaining access to resistance genes

In the drive to endow cowpea with resistance to pod borers and other postflowering insect pests, IITA is investigating the merit of moving resistance genes from a wild *Vigna* species (*V. vexillata*), which demonstrates excellent resistance, to the cultivated cowpea (*V. unguiculata* subspecies *unguiculata*). Direct crosses between cowpea and its wild relative have yielded embryos which are, however, not sustained in the pod by the mother plant. In the hope that such abortive embryos can be rescued and permitted to develop normally, IITA has developed a medium to nourish immature *Vigna* embryos in a test tube. (See photo at right.)

IITA researchers are, as well, trying to make the genetic transfer in stages, by "bridging" with crosses between compatible *Vigna* species, until the resistance genes can be introduced into cowpea itself. In 1994 IITA succeeded in crossing its first "bridge": in hybridizing *V. vexillata* with *V. davyi*.

Sources of resistance also exist in another wild relative, *V. oblongifolia*. In 1994, a resistant germplasm line of *V. oblongifolia* was crossed with a susceptible line of the same species, producing progenies that are expected to exhibit different levels of inherited resistance. From among these hybrids, IITA will attempt to identify the genes for resistance, helped by DNA markers that are associated closely with the genes that confer resistance. The aim is to find and clone resistance genes for use in transforming cowpea.

MUSA USMAN

The medium is the main message in this test tube: a medium developed to support immature embryos of wild relatives of cowpea. The 3-month-old *Vigna vexillata* pictured here was grown from a 4-day-old embryo.

Milestones for biotechnology

Biosafety Guidelines were developed for Nigeria with technical support from IITA to the Federal Ministry of Agriculture and Natural Resources. Nigerian scientists and policymakers met with IITA scientists during 1993–1994 to work out policy guidelines to promote safety in biotechnological research applications and uses of products.

New lab Construction of a new laboratory wing, with containment facility that satisfy biosafety standards, was completed. This extension to IITA's biotechnology laboratory was funded by the Italian government, as was the original laboratory.

Workshop The First Workshop on Implementation of Biosafety Guidelines in Nigeria was scheduled to be held together with inauguration of the new facilities during 1994; but circumstances dictated postponement of both milestone events to 16–20 January 1995. The Biotechnology Advisory Commission provided resource persons, while the Stockholm Environment Institute supported the biosafety workshop. The occasion fostered the kind of dialogue between scientists and policymakers that is vital for further information exchange and decisionmaking in this new field of scientific regulation.

The IITA insect museum at Benin Station, Cotonou, as a depository of specimens, was named as the regional identification center for BioNET-INTERNATIONAL to support national programs in West Africa and link them with institutions in the rest of the world. BioNET is a British initiative to improve cooperation among biotaxonomists in research for the tropics and by developing countries which envisages, among other activities, collaboration among insect museums.

Ecoregional research orientation

IITA enhanced the "ecoregional" perspective of its research program by reorganizing its whole agenda along the lines of agroecological zones or regions. (In earlier years, this perspective was associated largely with farming systems research.) Program activities were planned in 23 ecoregional projects for implementation from 1995.

The reorientation enhances focus on resource degradation problems and facilitates combination of natural resource management with production objectives. An ecoregional orientation provides a common perspective that will promote multidisciplinary effort and collaboration.

Collaboration in ecoregional initiatives and with "consortia" of institutions that share research goals increased in conjunction with the ecoregional perspective of research activity.

For full spellings of abbreviated names, see inside of back cover.

CONSORTIA of international and national research and development groups have evolved in recent years around specific issues and areas of concern. During 1994, RCMD participated in the development of three ecoregional initiatives:
• Global Initiative on Alternatives to Slash-and-Burn (with ICRAF the coordinator and IITA responsible for the Congo Basin benchmark area)
• Inland Valley Consortium (with WARDA as leader and IITA a contributor in characterization and GIS applications)
• Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (with IITA the convening center).

BENCHMARK AREAS are geographical areas that are defined according to important problems and opportunities for specific research domains. They are large enough to capture the essential biophysical and socioeconomic characteristics. Research partners, including development-oriented NGOs, can collaborate in benchmark areas to enhance results and avoid duplication (described in "New research partnership in the moist savanna", page 28).

In Cameroon, IITA and the national agronomic research institute defined and characterized a benchmark area of 15,000 square kilometers in the forest margins, which represents a resource-use gradient that extends from hunting and gathering in remote forest communities to intensive production in urban peripheries.

Resources invested in diagnostic studies and applied technology development in benchmark areas increased, while resources for characterization of agroecosystems were reduced, in IITA's resource and crop management research activities.

MOIST SAVANNA With concentration on the northern Guinea savanna, research themes were:
• agroecosystem diagnosis. Data were analyed for a 14-country characterization study. Results from Central Africa showed the importance of market access for technological innovation in farmers' lives.
• soil productivity. (See "The year in perspective" which precedes these highlights.)
• vegetation management. A computer-based "expert system" for selection of leguminous technologies, LEXSYS 1, was published and distributed among collaborators in research on sustainable, cereal-based cropping systems.
• cropping systems. The proportion of nitrogen fixed by soybeans in the soil ranged from 14% to 60%, depending on cultivar. (See "Natural technologies for sustainable food production" on page 33.) Regarding *Striga* control, soybean performed well on *Striga*-infested fields.

HUMID FOREST The program developed a concept for protecting fragile forest ecologies and improving farmer welfare, through cultivation of short-fallow systems and diversification in forest products. Research themes are:
• agroecological dynamics. Forest clearing had an immediate adverse effect on soil biota, such as earthworms and termites, which are vital elements in sustainable agroecosystems. Effects of burning off unwanted vegetation, a prevalent farmer practice, were analyzed in relation with soil chemical and physical properties, and subsequent crop growth.
• development strategies. Studies of alternatives to slash-and-burn agriculture showed that diversification in non-timber forest products will not be easy for forest-zone communities to develop, owing to insufficient local demand and high marketing costs.
• soil and plant management. Research on the problem weed *Chromolaena* revealed that shading and targeted slashing may be used to reduce its competition with crops. First results of a trial for improvement of soil organic matter content showed that mulches can do as much for root growth as liming.
• production systems. Alley cropping research confirmed that there is a need for a short fallow period, even for land under alley cropping.

AGROECOLOGICAL STUDIES A monograph was published on IITA methodology for characterization of inland valleys, based on remote sensing imagery (described in "Zooming in on backyard resources," page 24). IITA helped establish GIS capability in 14 countries by means of a workshop, provision of hardware and software, and follow-up training in-country.

New direction

New director of the Plant Health Management Division is **Peter Neuenschwander**, entomologist, who succeeds fellow entomologist Hans R. Herren. Founding director of IITA's Benin Station and Biological Control Center for Africa at Cotonou, Benin, Dr Herren left IITA after 15 years of service to become director of the International Center of Insect Physiology and Ecology (ICIPE).

Doyle Baker, economist, was appointed director of the Resource and Crop Management Division. He succeeds fellow economist Dunstan S. C. Spencer, who left IITA in 1993 after 7 years as RCMD director.

For full spellings of abbreviated names, see inside of back cover.

New *Musa* from Africa

FROM VISION TO REALITY

Africa's hybrid to beat the sigatoka scourge

Deep in the river delta country of southeastern Nigeria, at IITA's Onne research station for farming in the high-rainfall tropics, a handful of researchers "did what the experts said could not be done," in the words of one well-wisher. In their hands, the ingredients of good science—inspiration, sound knowledge, judicious risk-taking, and good luck—were combined in the right measures to produce hybrid plantain-banana cultivars for African farmers that can resist black sigatoka, a fungal disease that is one of today's worst threats to plantain and banana crops worldwide.

The development of the high-yielding hybrids brought IITA the 1994 King Baudouin Award, for the most outstanding achievement in international agricultural research in the past 2 years. The new resistant hybrids can be released to farmers after trials are completed among the 10 countries currently testing them. They are expected to replace existing susceptible and lower-yielding varieties within the next decade.

Of all the high points that characterize this award-winner—the tens of millions of consumers who will benefit, the miniscule investment in research (US$2 million), the new insights into the plant genetics that open new ways to overcome other production hurdles—the triumph is the breeding of plantain hybrids with seed from a sterile crop, an incredible feat which has not yet been matched in 75 years of effort elsewhere in the world!

And on top of that, in an incredibly short time—within just 5 years, the hybrids were developed with disease resistance and with high and stable fruit yields. That was only half the time which the researchers had set themselves to achieve their objectives. And that about halves the expectation of 8–12 years for developing a new cultivar of most food crops.

Plantain afflicted with black sigatoka can reduce yields to virtually nothing, as IITA scientist Rony Swennen and a Nigerian farmer noted in 1988.

WILLIAM CAMPBELL

Threat The black sigatoka disease itself grew to threaten plants of the genus *Musa* (almost all plantain and banana cultivars) worldwide within the short time of 30 years. Caused by the fungus *Mycosphaerella fijiensis* Morelet, the disease was first identified in Fiji in 1963, whence it spread to other Pacific Islands, Asia, and—10 years later—Africa and Central and South America.

Spores of the fungus are dispersed by wind and water, so no tropical place on earth is beyond their reach. The fungus establishes itself in *Musa* leaf tissues and causes brown streaks to appear. They spread and turn black, finally covering and destroying the leaf. (See photos, overleaf.)

This necrosis can destroy most of the leaves of a plant and sharply reduce photosynthesis. As a result, the plant can produce only small bunches of fruit. An infected plantation can lose one-third to one-half of its expected harvest. That threat to the economy and nutrition of Africans south of the Sahara is a severe one: an estimated 70 million people in the region consume the crop as one of their staple foods. The gross value of plantain and banana harvests in sub-Saharan Africa exceeds that of other staples such as maize, rice, and cassava.

All plantains traditionally grown by West African farmers are susceptible to the disease, as are many of the most widely grown bananas in eastern Africa. Fungicides can arrest the spread of the scourge, but their cost puts them well beyond reach of the African smallholders who grow and consume the crop. The risk of environmental contamination through long-term use also argues against reliance on chemical means. It was clear from the onset that the only satisfactory solution would be development of disease-resistant cultivars.

In Africa, black sigatoka was first detected in 1974 in Zambia, southern Africa, by FAO expert Roman Raemakers. In 1980 it was reported in Gabon, on Central Africa's west coast, where it may have been introduced some years earlier with planting materials imported from Asia. The disease spread from Gabon to its neighbors Cameroon, Congo, and Zaire. In 1986, IITA agronomists George Wilson and Rony Swennen discovered the characteristic leaf spots on plantain in a Nigerian farmer's field, which were confirmed to be symptoms of the dreaded disease by pathologist Ivan Buddenhagen. Shortly thereafter positive reports from farther west in Ghana and Côte d'Ivoire attested that black sigatoka was becoming pandemic.

EQUI NWUBU

Pollination of female plantain at IITA station at Onne, Nigeria, by staff member John Echoi.

Any new disease that threatens a staple food crop in Africa warrants concern early on, because disease can spread rapidly under tropical conditions and because any threat to the subsistence of farmers and the urban poor can escalate into economic catastrophe. Early in the 1980s African governments began encouraging IITA to start a campaign to control black sigatoka. IITA was well placed to do so, since Wilson had begun plantain research in 1973 together with Edmond de Langhe, a former plantain researcher in Central Africa, as a special project in cooperation with IFAD, Ghent University (1973–1976), and Catholic University of Leuven (1976–to date); the latter two collaborators with Belgian government funds. They convinced IITA management to undertake the work and laid down the research strategy for years to come.

New breed In 1987 IITA accepted the responsibility of breeding plantains and cooking bananas for Africa with resistance to black sigatoka disease. Work on *Musa* genetic improvement had commenced the previous year with crosses between plantains and wild banana. The goal was to build into the plant, over a 10-year period, black sigatoka

resistance and other characteristics that could overcome its worst problems among diseases, pests, and environmental stresses, and produce high yields with preferred cooking qualities.

A fallback strategy was also adopted, to promote a substitute for consumers should the disease reduce the supply of plantains before resistant hybrids could become widely available. Cooking bananas that were already resistant to the disease were introduced from the INIBAP transit center at the Catholic University of Leuven and propagated rapidly, with INIBAP support, in small plastic containers. They were offered as planting material to Nigerian farmers and organizations together with advice and demonstrations on how to prepare acceptable dishes from the fruit.

The success of the enterprise seems clear in retrospect, but in the making it was an unconventional and risky venture. It is a story of people and place—the scientists who pursued their vision, in a particular environment that had its own advantages and stresses.

Wilson, Swennen, and fellow agronomist Paul Devos, the first plantain researchers at IITA, had focused on questions of crop management and crop physiology—what made smallholder farming of plantains ecologically sustainable? Why would large-scale plantations rapidly lose productivity? The agronomic understanding they developed, of local plantain farming systems and farmers' needs, and their physiological knowledge of the plant, provided a solid foundation for the breeding program which evolved in response to the growing threat.

Devos and Swennen studied the taxonomy of plantains and bananas and collected *Musa* germplasm from late in the 1970s. Different *Musa* types have been cultivated in Africa for more than 2,000 years. They have evolved into different cultivars or "landraces" in particular areas or locales, partly through selection of preferred food qualities by the farmers growing them.

This "farmer-guided" evolution has also virtually eliminated the fertility or seed-bearing capacity of female plants of most of the landraces. Seedlessness makes them easier to eat, but extremely difficult to breed. By 1986 the IITA collection included 113 landraces, almost all those known to exist worldwide. Fortunately, some of them were capable of producing enough seed to use in improvement breeding.

Wild or cultivated bananas which already exhibited disease resistance were selected as males for crossing with the seed-fertile females. Pollen from the selected males was applied to the flowers of the newly opened bracts of the selected females (see photo, opposite) in experimental plots at Onne station, in a schedule designed to fertilize flowers at their most receptive time for setting seed.

Plantain females were selected as parents for their high fertility, for their seed-producing capacity. The most frequently used male parent was the wild banana "Calcutta 4" (*Musa acuminata* subspecies *burmannicoides*). It produces large quantities of fertile pollen. It has a high level of black sigatoka resistance which it readily transmits to its progeny.

The use of Calcutta 4 as parent stock was a radical departure from conventional practice—it is not cultivated, nor is it improved, and it produces small, inedible fruits. Ultimately, the wild Calcutta 4 did not transmit inferior fruit qualities to its progeny. The success with Calcutta 4 as a parent deposed the prevalent theory that the poor fruit size, or any other characteristic expressed by the wild male parent, would necessarily be transmitted to its progeny.

Tissue-cultured *Musa* crosses in the laboratory at Onne station, held by IITA technician Leonard Oragwa

EDUI NWOLU

Speedy solution Time was at a premium for the researchers, since black sigatoka appeared to be galloping across the region. The tactics of executing crosses between the landraces had to be faster than the usual 2 years between generations.

MARK WINSLOW

Multilocational trials at Ibadan campus show the effectiveness of black sigatoka resistance of an IITA plantain hybrid (at right), in comparison with a suceptible cultivar (left); happily demonstrated by IITA scientists from Onne (from left: Rodomiro Ortiz and Shaun Ferris).

Application of cellular biotechnology, using various tissue culture techniques, accelerated the pace of work of the breeding program.

Tissue culture involves laboratory work with *Musa* germplasm to a greater degree of precision than possible in nature. Tissue culture techniques permit rapid multiplication of selected stocks, improvement in seed germination through embryo culture, and safe movement of germplasm across national borders. All the genetic material in the IITA *Musa* collection could be brought into play practicably through tissue culture.

Tissue culture development fell to Dirk Vuylsteke, an agronomist who joined Swennen in 1982 and became a germplasm enhancer in the process. By 1984 the tissue culture lab was fully operational at Onne. IITA thus pioneered *Musa* breeding in a "test tube" environment.

Onne—the place—also figured in the constellation that spelled success for the venture. In 1979 IITA transferred its plantain research from Ibadan headquarters to high-rainfall riverine country near Port Harcourt, at Onne, next door to the Rivers State Institute of Agricultural Research and Training, with Swennen as the first on-station scientist. The climate there was better for developing crops and farming systems typical of Africa's humid forest zone. Located off a service road for coastal petro-industries, the remote station was operating without regular water and electricity supply, and only radio communications with headquarters. The annual budget for plantain research was $35,000.

The operational stresses apparently had a tonic effect, together with environmental influences on the plantain and banana plants, and produced the miracle of objectives accomplished in half the time estimated. The Onne team observed that environmental influences at Onne encouraged seed set in plantain, particularly the 10-month rainy season each year and a high phosphorus content in the soil.

Fertilization and seed set, the outcome of successful pollination, varies with humidity levels, total rainfall, solar radiation, and temperature. The researchers used weather data in targeting the optimal period for flowering and, consequently, seed set. Planting dates were adopted accordingly. They also found that success in pollination varies with time of day, as the female sexual part inside the blossom changes shape. The end of the dry season, just before onset of the rains, proved the most fecund time to obtain hybrids.

Seed production succeeded beyond imagined limits. The Onne average across the year was 2.4 seeds per bunch. In one instance, pollination at optimal time for flower receptivity produced a bunch of fruit with 203 seeds! Such rates could never have been predicted, considering that the research record elsewhere shows less than 1 seed per bunch.

Luck, too, played its part, as the essential companion to scientific endeavor, in speeding progress at Onne. The best 14 hybrids were produced during the period 1988–1990, with the champion of all the hybrids, TPMx 548-9, among the first batch harvested in 1988.

How it happened All that had driven the accomplishment was indisputable, but the theoretical genetics of the process had yet to be explained. It was vital for future *Musa* breeding efforts to have a genetic blueprint for the plantain hybridization. So in 1992, geneticist Rodomiro Ortiz joined IITA and began to unravel the complex genetics of the achievement.

IITA registered its first set of 14 improved plantain hybrids in the public domain, by publication in the international journal *HortScience* (28.9:957–959, 1993),

for unrestricted use by interested agricultural research or development programs. Another set of hybrids from the period 1988–1993, suitable as breeding stock, was also described in *HortScience* (30.1:147–149, 1995).

In those prolific 5 years of breeding work, more than 30 genetic sources of black sigatoka resistance were identified among IITA's collection of *Musa* germplasm. IITA research also found 37 cultivated varieties of plantain that were capable of bearing seed, nearly one-third of all existing landraces—contrary to the belief that plantain is a crop difficult to improve!

Plantain crosses produced around 10,000 seeds annually, although only 40% of them contained a well-developed, viable embryo. Test-tube germination of the embryo succeeded in 5% to 30% of the cases. In all, IITA researchers managed to establish several hundred hybrids in the field.

Taste tests, to study the potential acceptability of the hybrids to consumers, found almost no difference in taste between the hybrid TMPx 548-9 and the popular plantain Obino l'Ewai (its "mother"); although their fruit color differed.

IITA's partner programs in 9 sub-Saharan African countries and 1 in Latin America are collaborating in field trials of the plantain-banana hybrids. The continentwide trials are assessing stability of fruit yields over successive harvests, and the durability of the resistance—whether the resistance breaks down over successive generations.

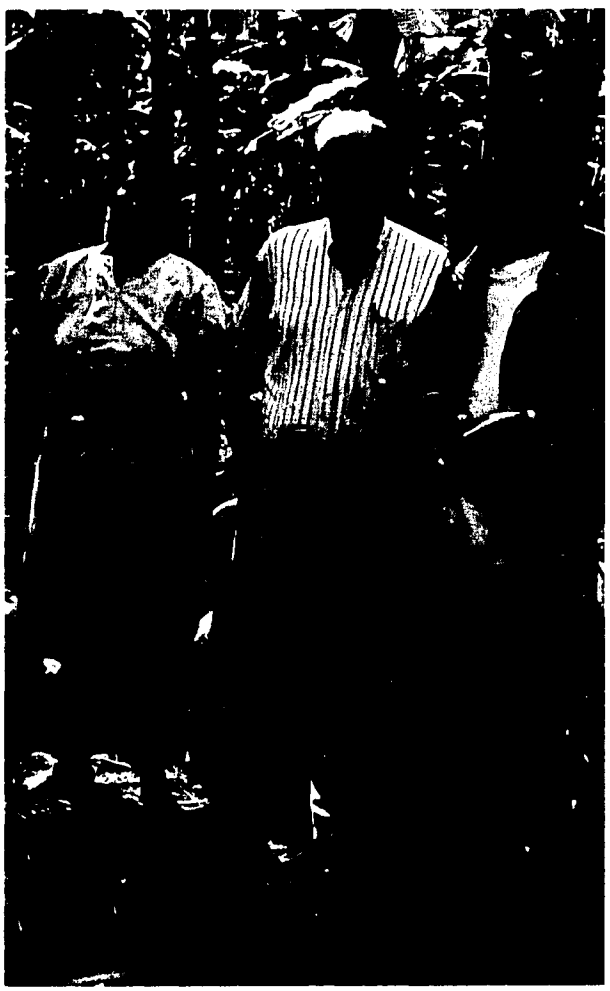
IITA and each country program are devoting researchers, funds, and material resources for the joint testing, ensuring that the benefits of research meet their objectives and are shared. IITA is helping national programs to develop their tissue culture laboratories as well, which will handle multiplication and distribution of hybrid planting materials for farmers, once the hybrids have proven themselves in the field trials.

While preparing for the ultimate use of the new hybrids, IITA has tried to estimate how great the economic impact of the research might be. The gross value of current plantain production in Africa is about US$2.8 billion per year, according to World Bank figures. The TMPx stock can potentially increase that yield by 225%, taking into account results from black sigatoka resistance, earlier flowering, and higher bunch weight. The annual gross value of production would thus rise to about $9 billion, if all the area currently under susceptible plantain stock is replanted with resistant hybrids and current prices remain constant.

The total costs to IITA of plantain-banana hybrid breeding over the 1988–1993 period, including scientific manpower and research support, was $2 million. The gain from that investment could be $6.2 billion. So, for every $1.00 invested in research, the return to the African economy would be $3,100.00. Even if only half the currently planted area is replanted with hybrids, the gain from each dollar's worth of research would be $1,550.00. Similar considerations would apply for Central and South America, because the black-sigatoka-resistant hybrids hold much promise for cultivation in that region.

Whatever calculations are eventually confirmed in reality, the drama of the achievement remains as encouragement for other researchers—to stick to their goals, no matter what adversity they encounter, if they believe they have the right ideas and can translate them into real steps of progress. That is, in essence, the story of science itself.

IITA scientist Dirk Vuylsteke with banana farmers in Uganda, where he is IITA's *Musa* breeder at the East and Southern Africa Regional Center (ESARC) at Namulonge.



RODOMIRO ORTIZ

Tailoring the product to taste

While the plantain-banana hybrids have saved plantain from annihilation, IITA is still working on ways to make the hybrid product and cooking bananas as appealing to consumers as possible. Naturally, people prefer what they have been accustomed to eating. Can, however, the flavor, texture, and other qualities of the new products somehow be made more palatable?

That's what IITA's plantain and banana improvement program is asking itself. Their postharvest research activities aim to determine (a) what are the qualities about hybrids and cooking bananas that people find inferior to traditional plantains; and (b) whether those qualities can be enhanced, so that the new products are acceptable as different but desirable foods.

In Ghana, for example, a taste panel at the Crops Research Institute in Kumasi found that "*fufu*" made with the hybrid is preferred to that with traditional plantain, because the hybrid has a smoother texture. (*Fufu* is a mash or paste which Ghanaians cook with pounded plantain and cassava in equal measure.)

In Nigeria, traditional plantain norms of taste, feel, and look still prevail. IITA's taste panel at Onne research station found, in trials during 1992–1994, that the traditional product heads the list in virtually all food preparations, although the hybrids are considered palatable.

Up market Postharvest researchers are experimenting with possible new products from the hybrids: bread, wine, vinegar, and other foods as well as soap and industrial starch. Hybrid plantain chips have already proved popular in trials.

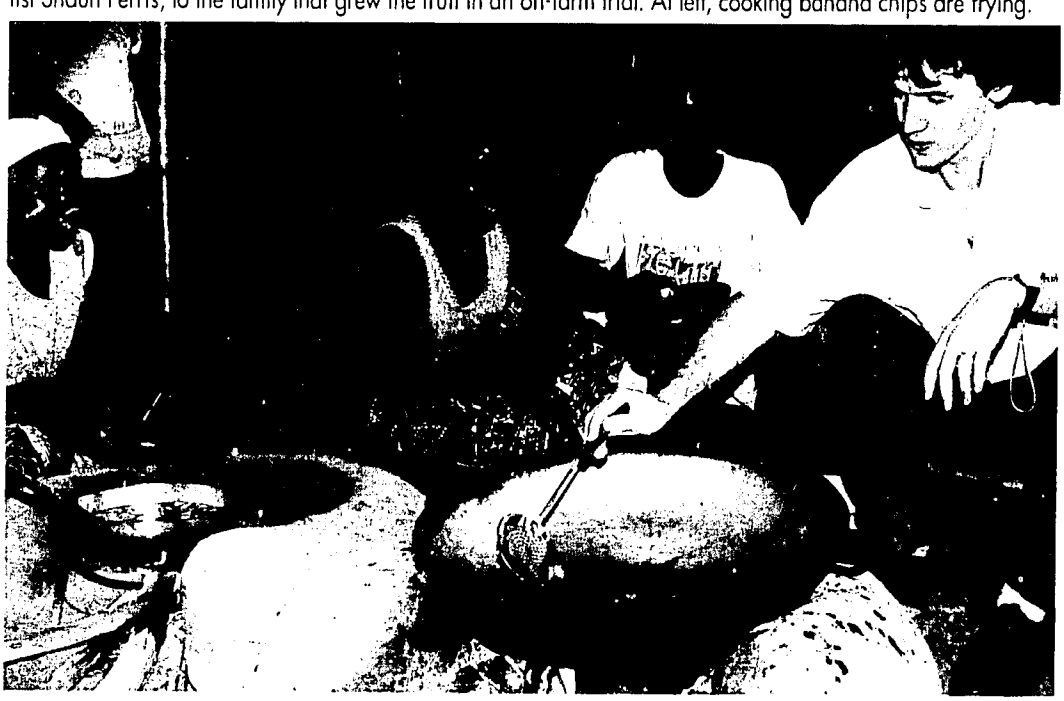
Basic studies are investigating the physico-chemical properties of the different hybrid cultivars, as well as the sensory impressions of consumers. Fruit durability ("shelf life", ripening, handling/storage aspects) and palatability (flavor, texture, response to cooking procedures) are the key qualities that breeders will in future have to develop.

The reseachers aim to draw up a quality profile for each of the hybrids in comparison with local plantain. Breeders will use the data in screening new hybrids for desired characteristics.

The cooking bananas, too, have yet to make a broad impact among consumers. All the selected cooking bananas outyield traditional plantains, producing heavier bunches with more fingers. Their shape, size, and color are, of course, considered inferior to those of plantain—apart from issues of taste and texture.

Feedback from farmers does, however, hint that the public can eventually accept cooking bananas. Many farmers themselves are satisfied to grow the bananas for their own consumption. One farmer reports that his wife can now sell his excess production at the market for half the price of plantain; whereas it had had no sale value when she first took it to market in 1989.

"*Mus-akara*" (fried patties of seasoned cooking banana and cassava meal), about to be served up by IITA scientist Shaun Ferris, to the family that grew the fruit in an on-farm trial. At left, cooking banana chips are frying.



EQUI NWULU

A MUST FOR *MUSA* PROTECTION
Ecosystems Management

Bananas and plantains are a way of life for many millions of farmers in the high-rainfall areas of tropical Africa south of the Sahara. Among the earliest food crops ever domesticated, they came to Africa over 2,000 years ago from southeastern Asia, where they originally evolved.

Such a broad range of them has evolved in Africa, under cultivation, that the Great Lakes region of eastern Africa is considered a secondary center of diversity for bananas, and West Africa a secondary center for plantains.

Today, for an estimated 70 million Africans, bananas and plantains are consumed in many different ways as staple foods, composing more than 10% of their carbohydrate intake. In the humid tropics across the continent, they are planted by almost everyone in villages, towns, even urban peripheries—in backyard gardens or field plantations of up to 1 hectare in area, mostly together with other food crops.

From an economic and environmental point of view, plantains and bananas are vital parts of sustainable cropping systems. Planted on highland slopes or river deltas, they help prevent soil erosion and provide mulch. They are also the most economical sources of dietary energy, in terms of cost per area cultivated or weight harvested. For most farmers they provide an important income source, akin to a bank account when the need for cash arises.

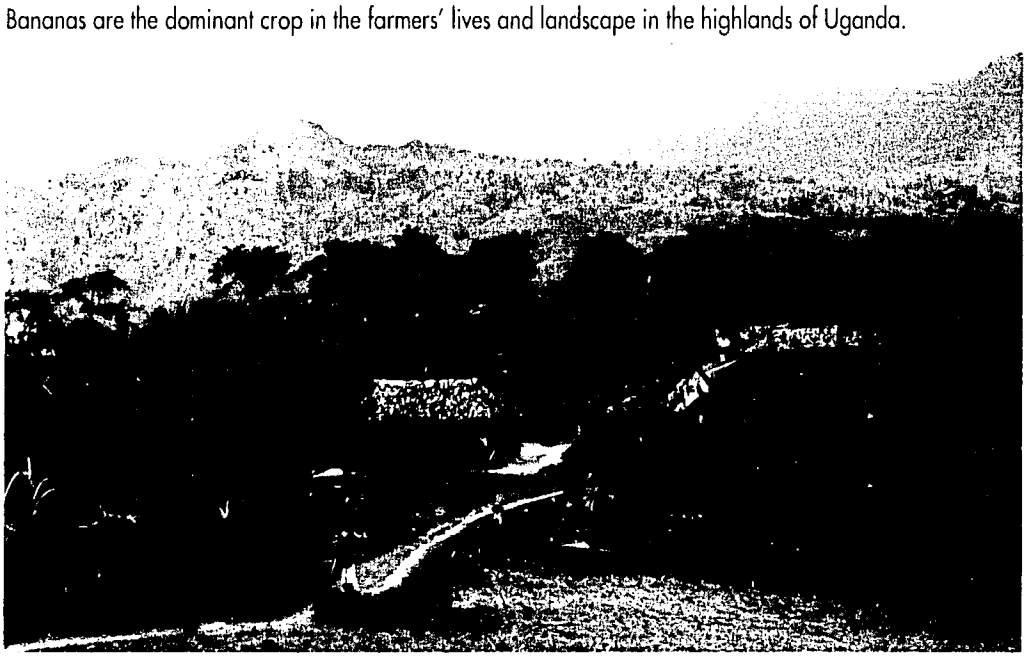
In recent decades, however, plantains and bananas have become more difficult to produce and more expensive for consumers to buy. Farmers have intensified production to keep pace with the growing population, but soils have become degraded as a result and output has actually declined in some areas. Pressure from pests such as banana weevils and nematodes (which attack the stem and roots, respectively) has accompanied intensified production.

To fathom the diverse environmental changes that impact the health of plantain and banana crops in sub-Saharan Africa, IITA began research on plant health management of *Musa* in the 1990s.

Needed: eco-understanding IITA's earlier work on pest problems had aimed at crop improvement with resistance to diseases (for example, see preceding article on black sigatoka resistance). The plant health problematique emerging in *Musa*, however, calls for new understanding of the ecosystems surrounding agriculture, especially the forces acting on agriculture. The goal is solutions to pest problems through biological control and other practical means, that can be sustained within the dynamics of the ecosystem.

As a first step, IITA began by investigating the extent and economic impact of *Musa* pests and diseases. For East Africa, surveys were completed in 1993 in Uganda to

Bananas are the dominant crop in the farmers' lives and landscape in the highlands of Uganda.



DIRK VUYLSTEKE

DIRK VUYLSTEKE

Making banana beer: juice from matured, green beer cultivars is processed by highland farmers in East Africa.

diagnose the pest and disease constraints in production of highland bananas. The East African surveys led similar work in West Africa, on lowland production of plantains, which began in Ghana in 1993 and Nigeria in 1994.

Basic biological and ecological research is accompanying the diagnostic surveys, investigating the specific interactions and effects of pests and diseases on plantain and banana crops.

The current research is evolving an approach toward the total ecosystem, whereby crops are seen in the totality of their interrelations with other parts of the ecosystem. The aim is analysis of constraints and ways to modify them so that crop production can rise to an optimal, sustainable level.

Plant health research in Uganda on highland bananas has already thrown some light on the problems accompanying the declines. First of all, the crop has long been cultivated in a sustainable system in Uganda. Well-managed stands can be found that exceed 100 years in age. In traditional banana-growing areas, production has declined without clear cause; although part of the reason appears to be deteriorating soil fertility (from intensified land use under growing population numbers), compounded by increasing weevil and nematode attacks. Black sigatoka disease recently arrived in Uganda.

With traditional landraces in decline, Ugandan farmers have begun to replace them with newly introduced types, or such annual crops as cassava, sweet potato, and maize. Similarly, in Rwanda and Burundi, farmers have switched some of their banana production from highland landraces to newly introduced cultivars.

In some areas, declining production has discouraged Ugandan farmers from expending effort in managing their highland bananas and brewing types.

Presumably in response to persisting market demand, cooking banana production has expanded in other, unaffected areas and has extended to new areas. The Ugandan government is very concerned that the forces behind the decline in traditional growing areas do not drive bananas from the new areas.

Uganda agenda IITA and the Ugandan National Banana Research Program (UNBRP) began collaborating in 1990, with Rockefeller Foundation funding support. The plan was to complete a rapid rural appraisal of crop health and production conditions as farmers perceive

Matooke bananas, mature yet green, are being peeled for boiling or steaming as the preferred staple food throughout southern Uganda (such as pictured here, at Namulonge) and elsewhere in the Great Lakes region.

DIRK VUYLSTEKE

Residents of a Rivers State village in Nigeria want to know about what ails their plantain gardens that don't produce as well as hoped. IITA pathologist Friedhelm Gauhl, on a diagnostic survey of plantain diseases and pests, peels a piece of corm (underground stem) to demonstrate weevil damage.

them, a diagnostic survey, and research on intervention strategies and technology development. UNBRP and IITA were responsible for pest and disease assessment. UNBRP undertook the identification and taxonymy of the bewildering array of cultivars under local names.

The rapid rural appraisal and interviews with farmers were conducted at 25 sites in southern Uganda during 1991. They sought to determine farmers' perceptions of banana production constraints and management options.

Farmers universally identified soil problems of declining fertility as their main production constraints. They cited banana weevil and ants (the species *Ondontomachas troglodytes* Santschi) as the main pests, without recognizing nematodes and diseases as separate causes of decline. Since most farms had been reduced to less than 1 hectare in area, farmers believed that soil and pest problems worsened under increasing population numbers.

The farmers described the best management options available to them as a shift from highland landraces, including cooking bananas, to introduced types or to annual food crops. The newer cultivars, including beer bananas, seemed to tolerate soil and pest problems and require less management. With limited cash or labor resources, most farmers felt constrained to direct them to cash crops (coffee, horticultural crops). Only farmers in the most commercial of growing areas regularly practiced cultural controls for banana weevil, such as trapping or destruction of crop residues.

The IITA-Ugandan team completed their diagnostic survey in December 1993. They collected data on banana pests and diseases from 24 villages. The results reveal that banana systems are extremely variable and complex. Maps have been composed from the data on distribution and impact of banana pests, including weevils, nematodes, leaf spot diseases, and *Fusarium* wilt. Analysis of the results and complementary studies on station and farms continues into 1995.

The team interviewed farmers to discuss results emerging from the survey. The farmers also completed a questionnaire about their management responses to banana pests and diseases as well as their sources and treatment of planting material. In 1994 the team conducted a rapid rural appraisal that focused on farmer selection of cultivars.

With the completion of the highland banana survey in Uganda, new knowledge about the extent and severity of pest damage to different cultivars enables IITA to begin development of control strategies and technologies. Survey results will be interpreted in the context provided by IITA research in related disciplines: genetics and breeding, biotechnology, agronomy, and postharvest uses.

The disciplinary research is directed toward the development of sustainable systems of plantain and banana production and use. The ultimate vision is a crop that resists pests and diseases and is cultivated by smallholders, who use improved genotypes and practices to produce high and stable yields.

Resource Management for Ecoregional Research

ZOOMING IN ON BACKYARD RESOURCES

Satellite Imagery Pinpoints the Potential of Inland Valleys

Sometimes the path out of a problem begins close to home. That is the case with the need to grow more food in West and Central Africa. Although much of the arable land is already cultivated and water resources are scarce, sizeable forest and savanna areas remain underexploited in farmers' "backyards"—in the inland valleys that lie along small streams.

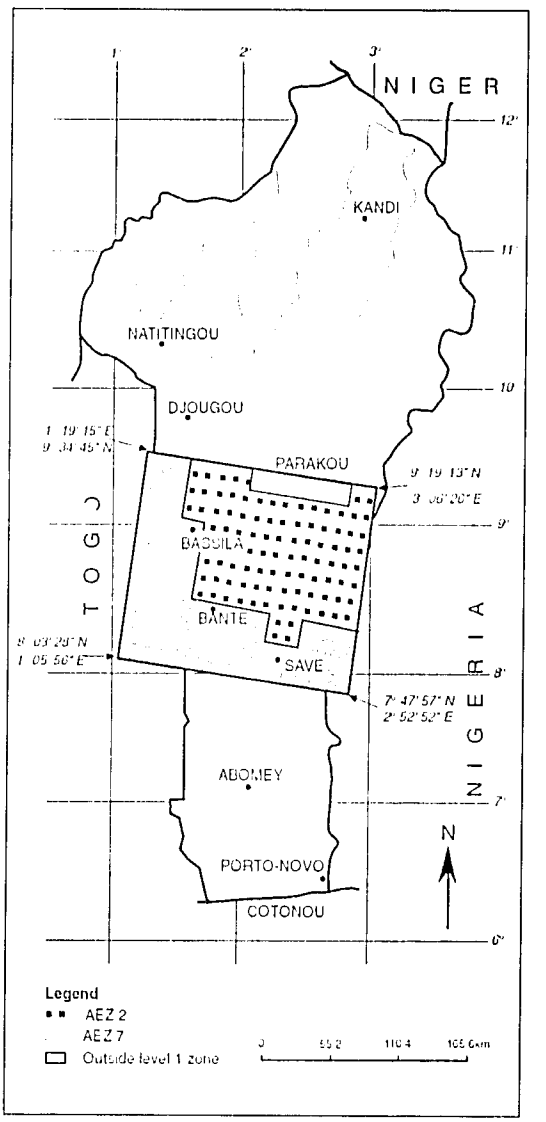
Inland valleys hold a rich potential for food production which agricultural researchers believe can be unlocked with the right kinds of technologies. Inland valleys here refer to the narrow, shallow valleys at the upper reaches of watersheds. IITA is studying inland valleys, comprising some 36 million hectares, which are spread across 14 countries in West and Central Africa.

In inland valleys, more water is available and the soils more fertile than in the uplands bordering them. Those conditions are favorable for intensive cropping. The potential of inland valleys for production gains is especially great in the moist savanna zone, where most West and Central African watersheds begin, and where the upland environment can support only one crop each year.

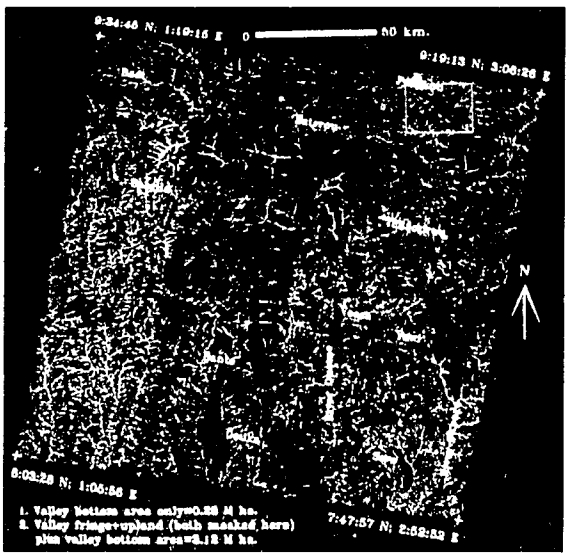
Land use is key in identifying areas of research concern. IITA has developed a methodology to characterize and map inland valleys and their adjacent uplands, according to land use, based on remote sensing data.

High-resolution satellite images from the American Land Observation Satellite with a Thematic Mapper sensor (Landsat TM) and the French satellite *Le système pour l'observation de la terre* with a High-Resolution Visible sensor (SPOT–HRV) provide the data for mapping. The images provide data which can be interpreted in terms of crops and other vegetation cover, moisture availability, the physical characteristics of inland valleys, the roads and settlements that may exist, among other features. IITA researchers verify the data through systematic checks on the ground, or "ground-truthing."

IITA's concepts and techniques are facilitating the research activities of the main international and national institutions interested in West and Central



The Landsat TM image outlined on the map extends across 3.12 million hectares of (in west-to-east order) Togo, Benin, and Nigeria. It includes 2 agroecological zones, as marked on the map: moist savanna (southern Guinea type; soils are luvisols) and derived savanna (or forest–savanna transition zone; also luvisols).



Inland valley bottoms are highlighted (and uplands blacked out) in this Landsat TM image of the framed area in the preceding map. Valley bottomland comprises almost 0.28 million hectares (9%) of the total 3.12 million hectares in the frame. Land-use data reveal that only 8% of those valley bottoms is being cultivated which testifies to the great potential for increasing food production in those ecosystems. (The "window" is enlarged in the illustration below.)

African inland valleys. At a meeting in June 1993, WARDA, France's CIRAD, Wageningen Agricultural University and Winand Staring Center in the Netherlands, and national programs of Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Nigeria, and Sierra Leone agreed to cooperate with IITA in its holistic approach to characterization of inland valleys with remote sensing techniques.

FAO of the United Nations has proposed extending the work to characterization and classification of inland valleys in East and Southern Africa, using the methodology that IITA had developed.

The rest of this article describes how IITA's methodology helps in analyzing the production potential of inland valleys.

Broad in area, deep in details It became apparent during the 1980s that inland valleys research needed the capability to deal with a diverse range of critical detail over large areas, in something more than a case-by-case approach.

Yet, the approach had to lead to productive solutions for the unique features or characteristics of each inland valley. Very few of them are alike, in terms of soil fertility, water availability, or local cropping systems. Research in any one valley is not likely to produce results which would be valid for another.

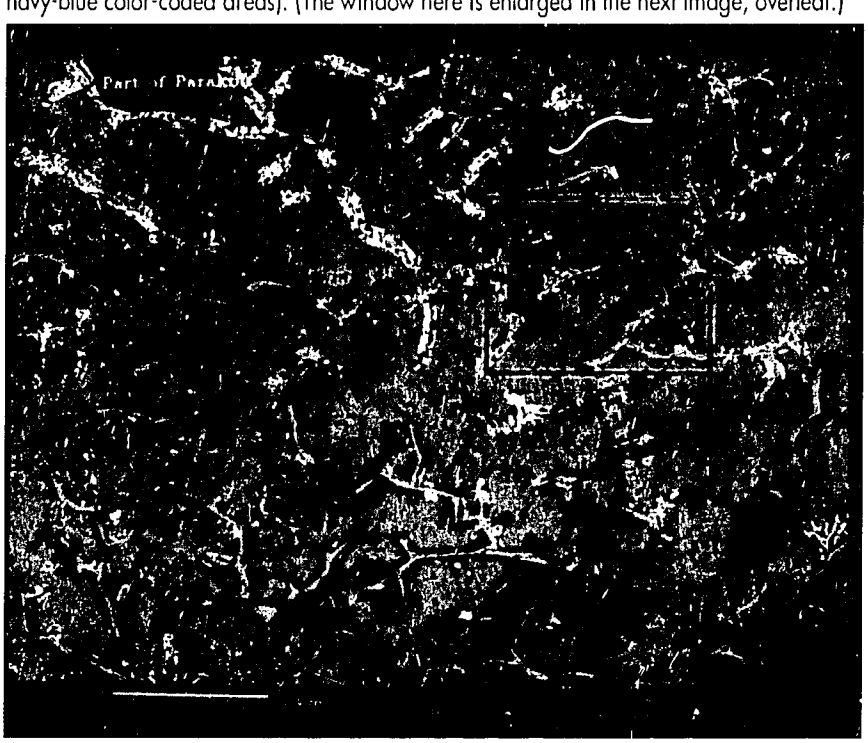
To enable research results to be effectively applied in a range of different valleys, researchers have to capture those differences in a common frame of reference—a set of characteristics broad enough to describe the diversity of features to be found among them all. Once characterization is accurate and complete, problems for research can be defined in ways that are amenable to analysis and action.

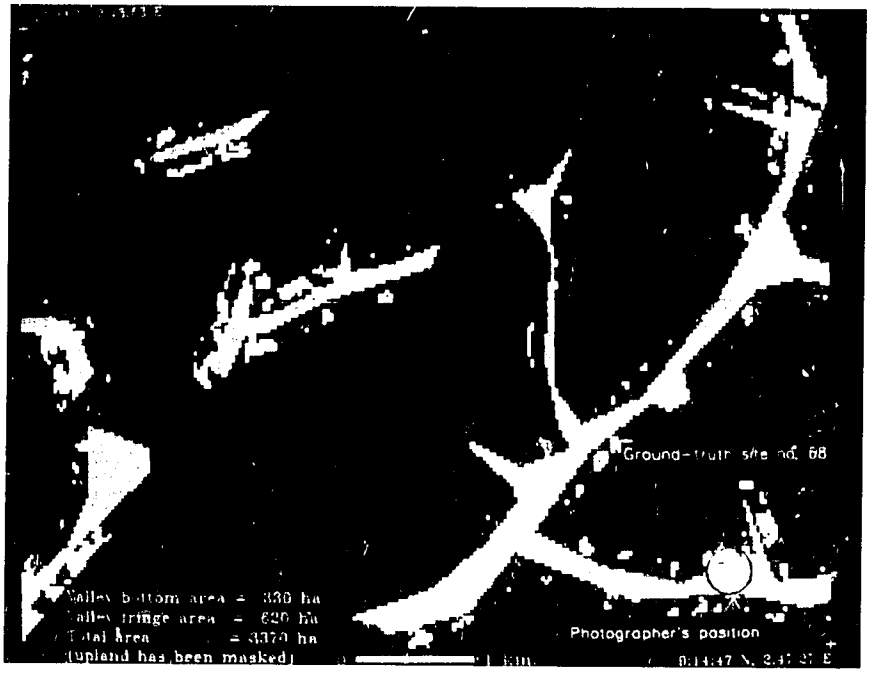
Several practical considerations guided decisions about how to proceed with valley characterization. First, the technology for mapping needed to cover a vast area with a consistent set of details, to include measurements of the valley bottoms and streams, and to show the recent status of roadways and settlements. Existing maps, based on topographical measurements and aerial photography, were inadequate and out of date.

Second, the researchers' aim to help farmers exploit the valleys also guided their job of characterization. They needed to discover the reasons behind intensive development in the most productive valleys. To do so, they had to examine land use across the landscape: valley bottoms, slopes and fringes, and uplands.

Fortunately, satellite imagery enabled researchers to study inland valleys on a continental scale and in

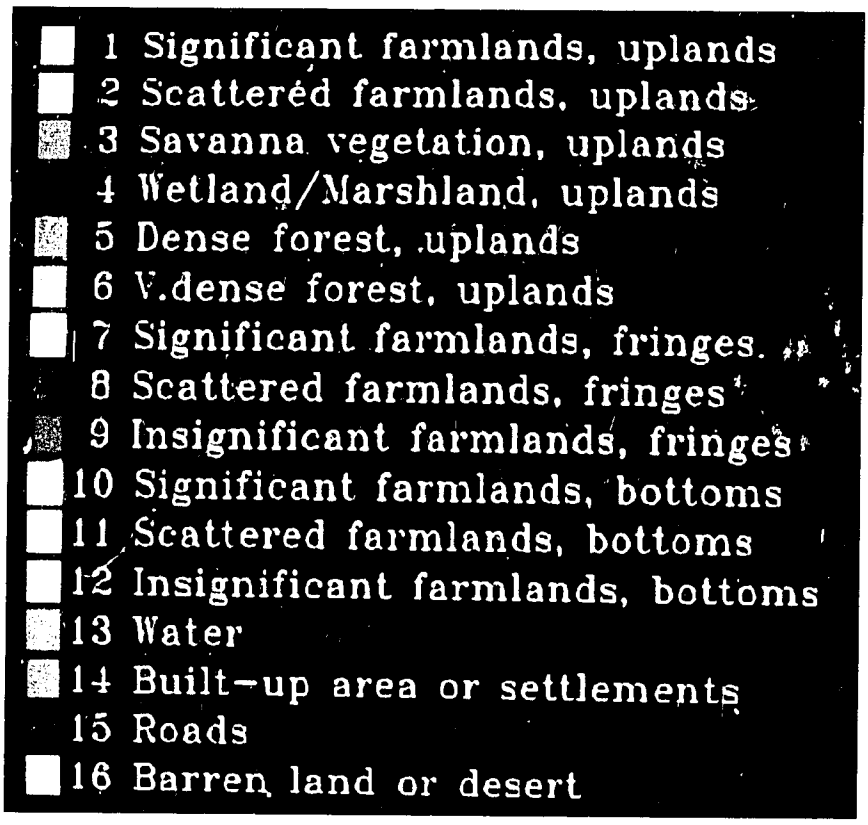
A window from the Level II image (see above) is enlarged to show land-use classes within this area of nearly 50,000 hectares. The characterization reveals that cultivation (in grey, white, and cyan/blue areas) increases with proximity to settlements and roads (in tan and navy-blue color-coded areas). (The window here is enlarged in the next image, overleaf.)





A window of 3,370 hectares, from the Level II image (overleaf), is enlarged to show a total 330 hectares of valley bottomland and 612 hectares of valley fringes; while uplands have been masked.

A circle (lower right) within this enlargement represents the area around ground-truth site no. 68 which appears in the photographs at right. The white areas inside the circle represent dense cultivation (currently barren because of the dry season), which appear in the upper photo of the valley fringes. The magenta/red color within the circle represents grassy uncultivated areas that appear in the lower photo of the valley bottom. Partially cultivated areas in the picture show up as yellow in the satellite image.



a rapid time frame. Without the aid of satellites, the process of compiling such maps would have been extremely difficult, costly, and time-consuming.

Each Landsat frame captures 3.12 million hectares (about the size of Belgium). Each SPOT-HRV frame covers 0.36 million hectares. (Three of them would cover Jamaica.) Satellite images are composed of pixels, each of which reflects an area of 0.09 hectare (30 × 30 meters) in a Landsat TM image, or from 0.01 to 0.04 hectare (10 × 10 to 20 × 20 meters) in a SPOT-HRV image. A single Landsat TM frame contains 230 million pixels.

IITA characterization methods call for reproducing the imagery at 3 different levels of magnification:

- LEVEL I FOR AGROECOLOGICAL ZONES — maps on a continental or "macro-" scale of, typically, 1:5,000,000 or greater. (See the general ecoregional map, page 5.)
- LEVEL II FOR REGIONAL AREAS — maps on a "meso-" scale (ranging from 1:100,000 to 1:250,000), which permits discrimination of some important production-related factors: land-use patterns, socioeconomic conditions (settlement patterns and roads), valley morphology (shape, size, slope), watershed features. To study characteristics at this scale, high-resolution (down to 20x20 meters) satellite images are useful. (See the 3 Level-II images, overleaf and at right.)
- LEVEL III FOR RESEARCH SITES — maps at "micro-" scales of 1:50,000 or less (on the order of aerial photographs), for identification of resources which relate to dry-season cropping. Very high resolution (below 20 × 20 meters) satellite images are appropriate at this scale.

For regional study IITA researchers classified the satellite images in a scheme of 16 categories of land use in valley bottoms and fringes, uplands, and other areas. (See the 3

PRASAD THENKABAIL

Ground-truth site no. 68 The lower photograph shows the inland valley bottom ond, beyond it, part of its northern fringe. The upper picture shows the northern fringe at close range. (The photographer's direction in each case is denoted by the arrows inside the circle in the satellite image, at left.) The grassy field in the lower photo is typical of uncultivated valley bottomland in the entire area of the Level II satellite frame under study. The northern fringe in the upper photo shows desiccated farmlonds during the dry season.

PRASAD THENKABAIL

images with accompanying legend in these pages.) The percentage of land cover afforded by 10 different categories—including vegetation such as trees, shrubs, grass, crops—were also established for each land use class.

Researchers check the details of image-based characterization during ground-truth missions, to a random selection of sites within the satellite picture. They correlate the data with their observations on land use, canopy cover, width of valley bottoms and fringes, volume of the stream flow, and local water control systems. They record information on cropping patterns, habitation and roadways, and dry-season moisture availability, which may also come from interviews with local residents.

In ground-truthing, researchers take readings of geographical position (latitude and longitude) from the satellite-based Global Positioning System, in order to "georeference" their satellite data with precise geographic coordinates. Wherever available, conventional (topographical) maps of the particular area can also supplement the data with observed detail.

Current state IITA and collaborating scientists have used their methodology to produce maps at regional (Level II) scale and identify promising areas for "benchmark" research. (See following article, from page 28.) Of greatest interest to the researchers, the characteristics on the maps describe the inland valleys and the conditions vital for agricultural production.

Researchers can, in areas with characteristics that mark specific stages or types of agricultural development, take benchmark measurements which help them assess the usefulness of new technologies in those particular areas, or how the technologies might be further adapted to make them useful. The results of benchmark-area research can indicate the suitability of different technologies for farmers in other inland valleys that share similar characteristics.

During 1994, IITA researchers teamed up with ILRI livestock specialists and WARDA rice scientists to establish benchmark sites in Nigeria for multidisciplinary work in technology testing over the next several years.

IITA researchers established the availability of vast percentages of uncultivated inland valleys. For example, only 8% of all the valley-bottom areas (280,000 hectares) shown in the first image (p. 25) has been cultivated.

Almost all this area can be exploited for cultivation if appropriate low-input technologies are developed for water control. At the same time, environmental concerns about biodiversity conservation and about methane emission from cultivated wetlands must be addressed, in order to balance people's needs for food with quality of life.

Realtime satellite images are currently used in some valley studies to gain an idea of the dry-season potential in the particular case. IITA researchers are exploring possibilities for upland crops to be grown in inland valley bottoms during the dry season, when inland valley bottoms may be the only places with enough moisture to support crops.

New Research Partnership in the Moist Savanna

Maize markets boomed in Nigeria during the 1980s, as farmers in the moist savanna zone got hold of IITA-improved varieties and fertilizer and multiplied their yields. The maize boom realized the dreams of the crop breeders—now it is the turn of agronomists to examine the sustainability of this phenomenon. How have farmers intensified their crop production? What improvements in resource management techniques would help them make it sustainable?

To investigate these questions, early in the 1990s IITA focused on the potential for crop increases in the northern part of the moist savanna zone, known as the northern Guinea savanna. Conditions there are good for cereals and other medium-duration annual crops. The annual growing period lasts from 5 to 6 months. Annual rainfall ranges from 900 to 1,300 millimeters. Solar radiation is favorable for cereals, at more than 500 calories per square centimeter daily, on average; while the cool nighttime temperatures help maize, for example, to conserve energy by reducing respiration rates.

Savanna soils are, however, sandy and contain little organic matter or nutrients such as nitrogen and phosphorous. They compact easily and form crusts, so that rainwater runoff erodes the face of every slope.

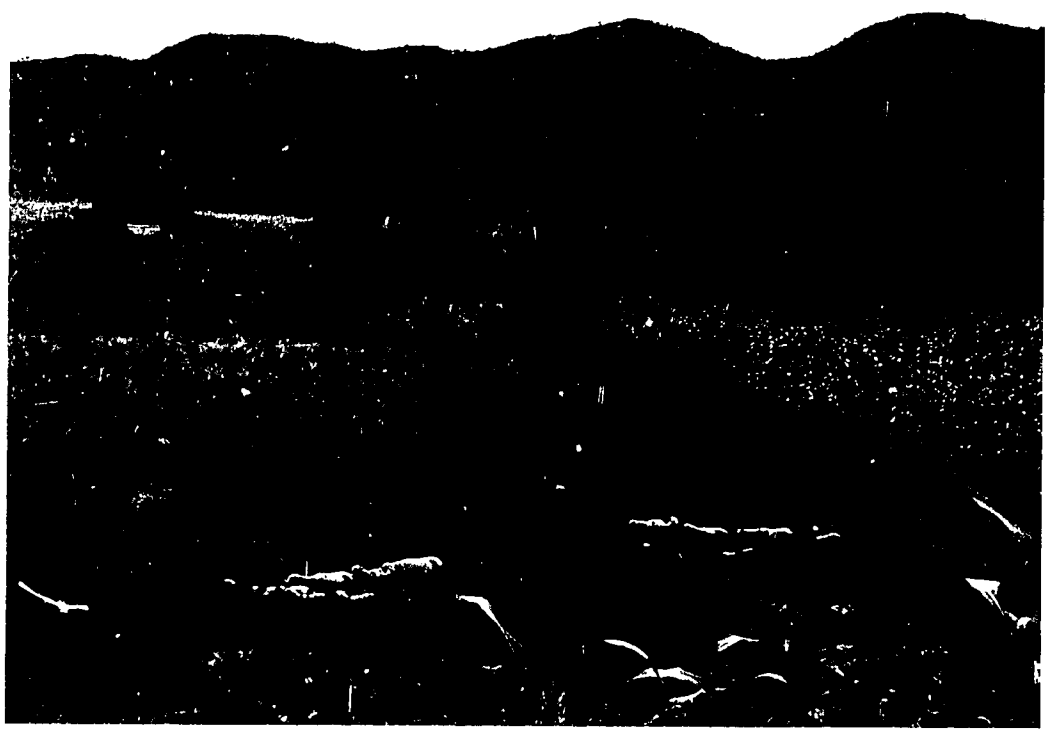
As farmers try to coax ever more crops from the soil, deficiencies of potassium, sulfur, and zinc are likely to occur. Without fallows to restore organic matter and plant nutrients, soil fertility declines. With the land under unrelenting pressure, the parasitic weed *Striga hermonthica* invades sorghum and maize fields to devastating effect.

IITA has started with several collaborators to test new technologies in two large areas of the northern Guinea savanna. The work involves farmers more extensively than ever before, in assessing the usefulness of technologies to meet their needs for modernized agriculture.

Interaction with farmers in large-scale testing, over the next few years, is expected to enhance the screening and refinement of technologies, and reduce lead times in adapting them to specific farming conditions. It should also enable national collaborators to expand research relations with farmers.

Ultimately, involvement of farmers will ensure the usefulness of the results and help cement their commitment in the quest for sustainable production systems.

Small savanna farms have profited from the maize boom, but researchers are concerned that production practices may imperil the resource base.



MOYO BOLARIN

IITA and ILRI researchers discuss with Bauchi farmers what the community would gain by participating in the technology trials.

Benchmarks With an agenda of technological development, researchers need to work with farmers to take benchmark measurements, for tracking improvements in the productivity of technologies being tested. In 1994 IITA designated two "benchmark areas" in the northern Guinea savanna with the characteristic physical and economic features of the region's agricultural environments. In those two areas, all parties with an interest in the problems—including researchers, development agencies, and farmers—began to adapt IITA technologies to the realities of the farm landscape.

In the real conditions of benchmark areas, researchers can work out hypotheses to help them determine what technology can work where, and under what conditions. Hypothetically, for instance, farmers in areas closest to settlements, roads, markets, or farmlands already successfully developed, would be most likely to intensify their production in future, using purchased chemicals or labor. Farmers in poorly developed areas would need different types of technology to increase production, depending on soil and other biophysical conditions.

The areas for benchmark research are large enough (10,000 to 20,000 square kilometers) to capture the diversity in characteristics, both biophysical and socioeconomic, that typify a region or part of it. The farming systems, constraints, and opportunities in each benchmark area have been clearly defined in a characterization exercise, so that research results can be applied later in similar areas targeted for development.

IITA distinguishes two main drives behind agricultural growth: either a population "push" or a market "pull". In "population-driven" areas, the need to feed more mouths prods farmers to increase their production. In "market-driven" areas, the possibilities for selling produce are attractive enough to enable farmers to increase production.

Next in importance in the characterization is the way in which farmers are increasing their production: either by expanding the area they plant or intensifying cultivation on existing plots. Both types of characteristics—what is driving growth and how growth is taking place—have a bearing on the selection of new technology that would enhance the growth process.

Technology needs are further differentiated by the range of prevailing physical and economic conditions. Benchmark areas have to be able to provide clear evidence for success in technology development—which new crop varieties and farming practices would work to improve farm productivity, and under what conditions.

Two benchmark blocks were chosen in different states: one in Bauchi, the other in Kaduna. IITA conducted both rapid and periodic surveys of farmers' resource flows in the Bauchi and Kaduna blocks during 1994, with help from WARDA and ICRAF on special topics. The aim was to collect baseline data for use in planning technology testing at farm level and, in future, to assess the impact of technologies developed for those areas.

Bauchi In Bauchi, in north-central Nigeria, poor soil productivity and poor road access to markets lead to relatively high prices for inputs and low prices for the resulting harvests. Growth in agriculture thus tends to be driven by population pressure. Three villages in the Bauchi block were chosen during 1993 for benchmark research into population-driven growth.

IITA had worked in the area since 1989 on maize and cowpea farming systems and postharvest

technologies, collaborating at various times with the Institute for Agricultural Research of Ahmadu Bello University, Zaria and the Bauchi State Agricultural Development Project. In one of the villages, Bajama, IITA began postharvest research in 1992 with the support of a local NGO, the Kunsumok Community Development Association. Since 1994, ICRAF has worked with IITA to assess the needs for multipurpose trees in the area.

Each Bauchi farmer or farm worker has to produce, on average, enough food to support 2 people, on approximately 0.8 hectare of land. Women farmers generally have one-third to one-half less farmland than men have. The subsistence character of life in Bauchi is revealed in the high proportion (90%) of their harvest which farm families consume.

Family size averages more than 9 people, varying from over 6 to 13. The wide difference in farm labor available to each family will influence the technology options to be developed for the various village sites.

So great is the pressure on the land in Bauchi, that only 15% of the cultivated fields has ever been fallowed. At the same time, less than 5% of the fields is manured. Harvested crops are entirely removed from the fields for threshing, in the traditional way. No residues are plowed back or returned as mulch, except in household gardens. Soil nutrients are thus exported and not replaced through fallows or manure. So, soil fertility inexorably declines, shrinking harvests.

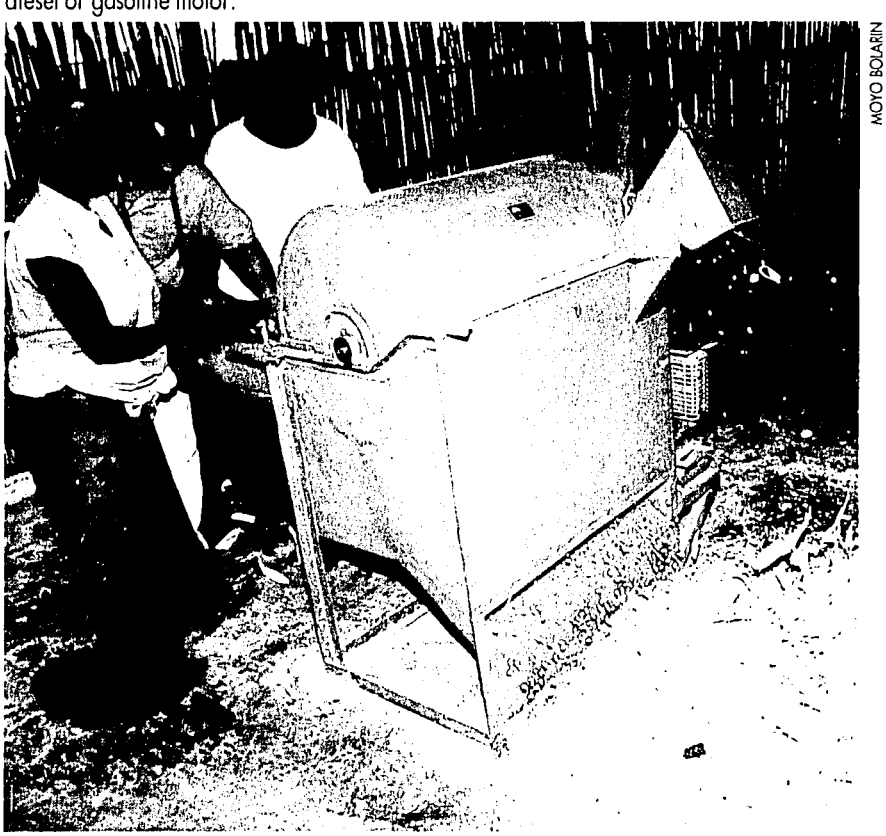
To counter this decline, IITA began testing improved ways of rotating and intercropping grain legumes, such as cowpea, soybean, and groundnut, with cereals during 1994, as one type of solution in the Bauchi block. Screening of herbaceous legumes continued, while

MOYO BOLARIN

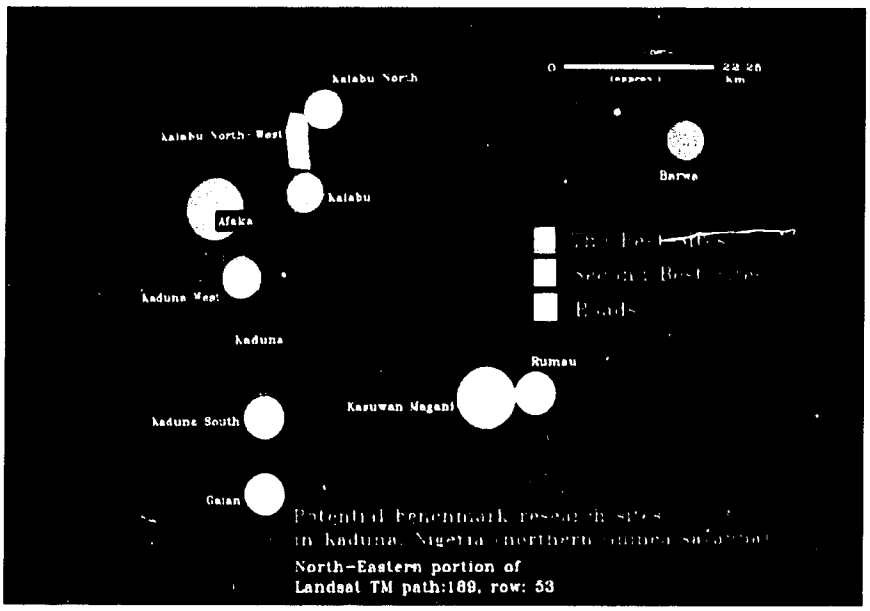
Here in Bauchi, innovative equipment creates opportunities for men and women to share farm chores.

TOP: The men's knapsack will release its burden of ripe maize, after a tug on the ties at the bottom. The woman's apron can hold 20 kilograms or more, was tailored locally at low cost, and is popular with men, too! IITA introduced the cart-and-digger combination (handle detaches from barrow to expose rake-like tines that help dig up root crops) in 1991 with Ford Foundation support, and it still is going strong.

BOTTOM: Threshing is no longer a dull or heavy job, with IITA's multi-thresher. Now both men and women want to get into the act! Postharvest design engineer Y. W. Jeon shows how to feed it ears of maize to be husked and shelled. Capacity is 500 kilograms per hour of maize, or lower volumes of grain legumes, rice, or millet, with a 5-horsepower diesel or gasoline motor.



MOYO BOLARIN



EQUI NWULU

Potential sites for benchmark research in the states of Kaduna, Nigeria; northern Guinea savanna. (Landsat TM path:189, row:53; northern portion.)

plans were made to test some agroforestry systems.

A special survey of postharvest activities and equipment in Bauchi during 1994 revealed that each farmer produces an average of 0.21 metric ton of cereals and 0.11 metric ton of grain legumes each year. The cereals undergo 10 processing stages at most before they are cooked for eating, while grain legumes require only 6. From 60% to 80% of the harvest is ground at community mills, which are mostly motorized. Households have their own manual equipment to grind small quantities, as needed.

In the eyes of IITA postharvest researchers, villagers' needs for improvements are highest for maize, sorghum, cowpea, and groundnut processing. With the villagers' help they are evaluating the economic aspects of crop processing, especially labor use and input costs/expenditures, to compare efficiency of existing methods with proposals for new technologies.

Kaduna In the Kaduna-Zaria subregion to the west of Bauchi, by contrast, market forces have promoted agricultural intensification. Farmers there enjoy better benefit/cost ratios for two reasons. Appropriate technologies (improved maize varieties and nitrogenous fertilizers) are available. Road connections to neighboring villages and proximity to the Kaduna state capital provide better access to markets than in Bauchi.

A location to begin market-driven research was selected in 1994: the village of Kasuwan Magani. In the selection process this time, surveys were complemented by remote sensing applications by the inland valleys research group (see preceding story on inland valleys; and photo, right). The village also has the attraction of inland valleys which can be cultivated during wet and dry seasons.

Cowpea traders flash handfuls of bills on an energetic day in the marketplace of Kasuwan Magani, putting a focus on the way market access stimulates technological changes in savanna farming.

EQUI NWULU

In Kasuwan Magani, each farmer has more than 3 consumers to feed. The average household consists of 12 members, with less than 4 working farmers. Average farm size is much larger than in the Bauchi block, at 1.5 hectares, distributed over 13 separate plots.

An idea of productive capacity was gained from surveys in other, similar villages in the northern Guinea savanna. Those surveys estimated that each farmer produces, on average, a harvest

EGUI NWOJO

IITA, ILRI, and national program staff assess prospects for collaboration in Kasuwan Magani. The inland valley bottomland is almost lush with plantain, maize, sugarcane and other crops, despite the time of year: dry season, in March.

of 5 metric tons of cereal crops and 0.1 metric ton of grain legumes.

Kasuwan Magani shows the essential characteristics of market-driven farm production. Maize and rice occupy half the planted area, while little sorghum is grown. The emphasis reveals that the farmers grow food crops to sell as well as to consume themselves. While they grow a greater variety of crops than farmers in Bauchi, they plant fewer crops in each field at a time, aiming at market sale. Hired hands provide more than half the work required in all the farm operations.

Prominent among the cowpea types grown is the local variety, achis*huru*. A cash crop, it is planted early in the rainy season and harvested 2 months later, without application of any agrochemicals. Its prevalence and timing suggests that it plays a role in sustaining cultivation of cereals and other crops in fields which are otherwise not left to fallow.

Greater use of grain legumes or cover crops as "fallows," concurrently with regular farming, might help the farmers of Kasuwan Magani to boost their harvests. Research during 1994 included screening of leguminous cover crops to enhance soil fertility. Trials of improved maize and cassava varieties also began, and cowpea storage. In 1995, IITA will begin to quantify the nitrogen contribution of a*chishuru* in sustaining soil fertility under intensive cropping.

Partnership The Kaduna State Agricultural Development Project has assisted IITA in most of the activities at Kasuwan Magani. IITA worked mainly with the Kaduna ADP in assessing the several possible sites suggested by remote sensing evidence (see photo) and in making contacts among local farmers and communities. Another Nigerian partner, the Minna State Technology University, has agreed to start nurseries in 1995, for the supply of multipurpose tree species for trials at both Bauchi and Kaduna benchmark sites.

Among the international centers, WARDA and ILRI joined the group during 1994. WARDA researchers launched joint trials with farmers while ILRI assessed possibilities for livestock projects in 1995.

WARDA teamed up with farm families in making the selections for the researcher/farmer-managed trials of 12 improved varieties of rice. Men and women farmers helped select varieties on the basis of yield and general field performance. Farm women selected some varieties for their food quality, based on cooking and taste tests.

In these ways, to date, researchers have enlisted farmers in studying how well existing technologies suit the northern Guinea savanna, and whether they should be modified or new ones designed.

IITA with its partners in benchmark areas is well-placed to develop technologies for the northern Guinea savanna. Once an idea is proved in the field to be an effective solution to a crop production problem, IITA passes the technology to other researchers in the savanna to adapt to local conditions.

In this way the benchmark sites are a focal point for all collaborators examining the field performance of technologies in farmers' cropping systems. As the need for adaptation or modification becomes apparent, each collaborator can contribute according to its specialties.

Natural Technologies for Sustainable Food Production

Natural principles for resource management should be the least costly and most reliable means of helping farmers to overcome soil problems and increase their harvests. IITA research has focused on three systems in particular for the moist savanna zone. They provide technologies which protect the soil against adverse climatic conditions and increase crop yields.

In 1994 IITA-led research began adapting them, together with other technologies, for use in the savanna benchmark sites:

LIVE MULCH SYSTEMS– low-growing cover crops are planted to suppress weeds, prevent erosion, and fix nitrogen in the soil which nourishes the food crop that shares the same field. A live mulch does not compete substantially with the food crop. That allows farmers to improve their soils at the same time that they produce their traditional crops.

SHORT-TERM FALLOW CROPS– fast-growing herbaceous legumes are planted as ground cover to fix large amounts of soil nitrogen and smother aggressive weeds. Some need to be grown as sole crops (unlike a live mulch). Some are relay-planted with food crops, to minimize competition (see photo of mucuna, overleaf). Some erect species can be mixed with food crops and not jeopardize the harvest. As a crop for short-term fallows, they enrich the soil with deposits of nitrogen that can help improve yields during the next season.

ALLEY CROPPING (HEDGEROW CROPPING)– multipurpose shrub or tree legumes are planted in rows between food crops. The leguminous species add nitrogen to the soil, while leaf litter and prunings contribute organic matter. The leaves and branches also provide fuelwood, livestock fodder, and staking material for climbing plants. The dense rows protect the soil against erosion and the crops against foraging livestock. Alley cropping is designed to sustain crop production over the long term, especially on sloping land.

To these technologies are added improved crop varieties, and crop management practices which include measures to protect plant health. They are combined selectively, for farmer-managed trials under specific conditions in the benchmark sites.

Mucuna One leguminous cover crop has already become popular in West African countries where it has been introduced: "velvet bean" (*Mucuna pruriens;* see photo, overleaf), in alternation or relay-planted with maize.

In Benin, for example, farmers have accepted mucuna as a short-term fallow for two reasons. It enriches exhausted farmlands with nitrogen within only 1 or 2 seasons of planting. Also, its canopy over-

EQUI NWULU

Farmers in the benchmark research area of Kasuwan Magani usually remove crop residues after harvesting and burn the remainder. Erosion and depleted farmland are apparent results here. Farmer-researcher participatory trials need to reverse this deteriorating situation with soil-restoring systems described above.

whelms the farmers' old enemy "speargrass" (*Imperata cylindrica*), preventing the new shoots of the noxious weed from receiving enough sunlight to proliferate.

The effectiveness of mucuna hinges on particular conditions and interactions in the soil. IITA is investigating how mucuna becomes established in inhospitable soils and how it contributes its nitrogen. This research explores new territory. The results should help in reinvigorating spent soils in the West African savanna.

Another valuable lesson for researchers from Benin's rapid adoption of mucuna lies in the farmers' motivation. Farmers were willing to relinquish traditional cropping practices when the rewards from adopting different practices appeared to be substantial.

In this case, the rewards did not come immediately with the crop, but lay in the productivity of subsequent food crops. That "delayed" reward in itself shows that farmers are ready to take a long-term view of their risks.

Roots The roots of mucuna, as with all leguminous species, are invaded by bacteria in the soil known as rhizobia, which infect the roots and cause them to form swellings or nodules. Successful infection enables the nodules to bind, or fix, nitrogen from the atmosphere and to leave it in the soil as nitrogen deposits when the plant dies.

Soil microbiologists at IITA have suggested that mucuna nodulates effectively with the slower-growing rhizobia of the genus *Bradyrhizobium*. Faster-growing species of the genus *Rhizobium* are able to form nodules with mucuna, but they are ineffective in fixing nitrogen.

After the right rhizobia have been identified, a puzzle remains unsolved: what allows a mucuna crop in one farmer's field to produce successful nodules with a lot of nitrogen, while in another field (or another part of the same farmer's field) the nodules on the mucuna roots have little nitrogen to show? The specific nature of the relation between a rhizobial strain and a mucuna variety needs to be investigated further, so that scientists can help farmers to realize benefits from effective use of mucuna.

Apart from the right rhizobial strain, availability of phosphorus in the soil also influences how well mucuna nodulates and fixes nitrogen. Insufficient phosphorus limits the plant's ability to nodulate and fix nitrogen.

Where phosphorus is scarce, farmers may be able to rely on another microorganism, those fungal associates of rhizobia known as vesicular-arbuscular mycorrhizae (VAM), which can assist the plant to

A field of "green gold," as farmers in Benin call mucuna. Farmers value its soil-enriching benefits and weed-smothering canopy. The rapid, widespread adoption of mucuna in Benin puts to rest notions that traditional farmers find it difficult to change traditional practices.

MOYO BOLARIN

take up whatever amounts of phosphorus are available. Again, it is a matter of identifying those strains of VAM present in the soil which are compatible with the mucuna.

The crux, for the scientist and ultimately for the farmer, is that enough of the right strains of rhizobia should inhabit the area to be planted. If the concentration is too low, it can be raised through inoculation of the mucuna seed with rhizobial cells before planting. IITA researchers believe that inoculation is warranted where the concentration in the soil falls below below 10 rhizobial cells per gram of soil.

Bottom line When mucuna and rhizobia nodulate to best effect, the farmer can expect to capture from 60 to 200 kilograms of atmospheric nitrogen in each hectare. This yield comes from mucuna planted alone in a field, at 12 weeks after sowing.

When mucuna is planted together or in tandem with another crop, it grows less prolifically and usually fixes atmospheric nitrogen at a reduced rate (about 40% less than mucuna grown alone, in recent IITA experiments).

In either case, the farmer benefits from nitrogen deposits which reduce his or her need to purchase nitrogenous fertilizer. For example, a maize harvest from a field earlier planted to a mucuna crop was approximately the same as that from an equivalent field which had not benefited from mucuna, but which had received 120 kilograms per hectare of nitrogen fertilizer.

A mucuna/maize rotation system can thus help reduce farmers' expenditures, while enabling them to increase production on the same plot of land.

A soy solution In separate work in 1993 to test how well soybean nodulates with the rhizobia which naturally occur in farmers' fields, researchers from IITA and NiFTAL have shown that it nodulates with cowpea rhizobia and that nitrogen accumulates in the usual way. The harvests (of IITA-improved soybean) were also similar, whether or not the seed had been inoculated with rhizobial spores.

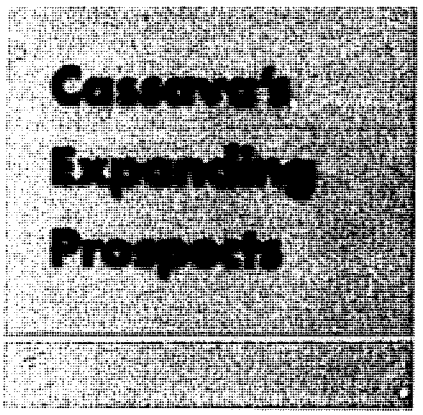
The evidence that the "tropicalized" soybean can nodulate promiscuously with indigenous rhizobia rounds out IITA's pioneering research of two decades earlier, which adapted soybean to the farming conditions of West Africa. While local rhizobia have evolved to suit cowpea, their efficacy with improved soybean has been demonstrated.

The research also provided the opportunity to demonstrate that soybean/maize rotation systems are useful for farmers who can purchase little fertilizer, if any. The results also show that IITA-improved soybean has a favorable impact on the yield of a succeeding maize crop.

Maize yields increased after a soybean crop (see accompanying chart) even though all the harvested soybean plants were removed from the field to be threshed elsewhere, following local custom. No soy plant residues were left above ground which could have served as natural fertilizer. The reason why the soybean/maize rotation benefited the maize crop needs to be studied.

The findings of nitrogen-from-soybean research need to be assessed with results from work in the benchmark areas, as well as earlier on-farm research, in order to show how these findings can best be applied in relation with existing technologies.

IITA and its national and international collaborators have created options for savanna farmers to improve their soil fertility, while increasing their food production. The available soil-enriching technologies, together with other innovative practices for farmers in resource and crop management, need to be implemented in sub-Saharan Africa, as means to reverse the regional trend of declining growth in food production. The results of adoption and promise of new findings ensure that the twin effort to improve food security and sustain environmental resources will be part of new farmer-researcher participatory endeavors.



Abundant Future for African Cassava

While food shortages in sub-Saharan Africa regularly capture world headlines, the good news is that the yields of new varieties of cassava, one of the region's main foods, have risen in Nigeria at the same time as populations have rapidly increased, farming methods intensified, and market conditions improved.

IITA scientists expect that the Nigerian experience can in future be repeated in all cassava-growing areas of sub-Saharan Africa—provided that conditions are as favorable as those in Nigeria, where farming and market opportunities have enabled farmers to adopt the improved technologies.

This prognosis for cassava comes as the culmination of a 6-year survey of cassava production in 15 countries across sub-Saharan Africa. The Collaborative Study of Cassava in Africa (COSCA) was organized in 1988 with funding from the Rockefeller Foundation. COSCA is based at IITA, which works in the field with CIAT, the Natural Resources Institute of the UK, and the national programs of each survey country.

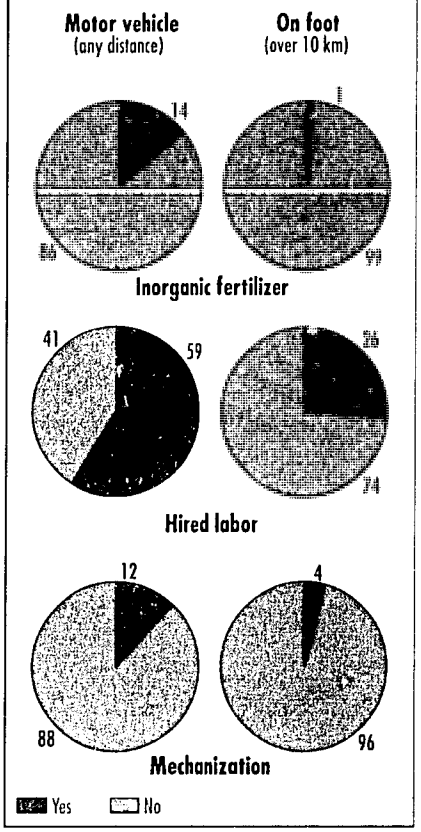
COSCA survey results can suggest for us the future of cassava because of their consistency and the wide scope of conditions they represent.

Dynamics The essential fact to understand about the dynamics of Afri-

ERIC TOLLENS

Bundles of cash offerings greet itinerant cassava traders, *"parcolis,"* arriving in Kinshasa from the Bandundu–Kikwit region to the east. Cassava is no less commercial a crop than any other, here in Zaire; a popular staple for its protein-rich leaves as well as its root flesh.

Farmers' use of purchased inputs, according to their access to markets



can cassava production is that cassava is cultivated as a commercial crop, no longer just as a subsistence crop. On average, 45% or a bit less than half of a village's harvest is sold, not consumed by the grower. Farmers buy fertilizer and hire labor to help them produce cassava, much as they do for other field crops. The extent of mechanization in transporting the harvest, and processing it, is as high for cassava as for the others, too.

The consequences of commercialization for cassava root yield are clearly positive. The more farmers use fertilizers for cassava, the greater its average root yield. The same holds true for use of hired labor.

Farmers' use of purchased inputs such as chemical fertilizer, hired labor, and mechanized services appears to increase as the farmers gain better access to markets and cash returns for their harvests. Hence cassava yields also grow with improvement in farmers' accessibility to markets. (See chart at left.)

Root yields are, therefore, substantially higher in areas with high commercial opportunities than in less commercial areas.

Farmers in the more commercial areas, however, often follow two counterproductive practices that work against high yields:

1. They harvest cassava early for sales purposes, before the root has reached maximum size.
2. They space the cassava at densities which often are above optimal for plant growth or yield.

Nonetheless, with all the influences and interactions taken together, farmers with better access to markets tend to produce better yields.

MOYO BOLARIN

These farmers in southern Benin, who live close to markets, have not permitted their cassava roots to "bulk" or fill out to the maximum extent possible, preferring to plant their crop at a high density in the field and to harvest it early for sale. This pattern is typical of many farmers continentwide who enjoy good market access.

Malthusian The Malthusian apocalypse is not borne out in the COSCA analysis of how population pressure actually impacts on cassava yields.

Population density as well as cassava varieties may differ from place to place, but the cassava yield across the sub-Saharan region has stayed at a consistent average level. COSCA has calculated that general average to be 11.9 metric tons of fresh roots per cultivated hectare.

The reason why the gross cassava yield stays much the same, across areas experiencing different population pressure, becomes clear with an understanding of how farmers intensify their use of the land.

First of all, increases in population density force farmers to make changes in their production system. They adopt new farming practices in order to enlarge their cassava harvests from a given land area. They replace traditional practices with new ways which increase their productivity, intensifying their systems in a modernization process.

Under pressure to feed more mouths with each harvest, Nigerian farmers have curtailed their practice of fallowing fields as a measure to restore fertility. However, they have also taken up other, beneficial practices—such as grazing of livestock and use of the organic manure supply to fertilize their cassava fields. Farmers appear to manure their cassava fields to a greater extent in villages with high population density than in less populated villages. (See chart, above.)

Another sign of intensified land use shows up in the practice of burning stubble or fallow growth (the "bush") to prepare the land for new cultivation. Bush burning is a means of clearing land and fertilizing it with the residual ashes that declines as population density increases, as fields are no longer fallowed, and as other signs of agricultural intensification materialize.

Organic manuring in itself is not enough to raise yields in densely populated villages, because of the counterproductive plant densities and early harvests of cassava which are popular with farmers under the pressure to intensify.

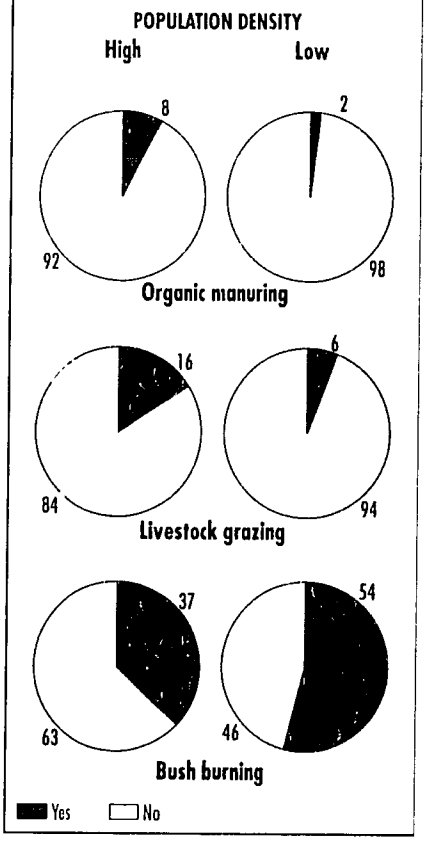
So, while increases in population density do not directly raise or lower cassava yields, many other changes occur as a result in the cassava production system which can help to raise yields.

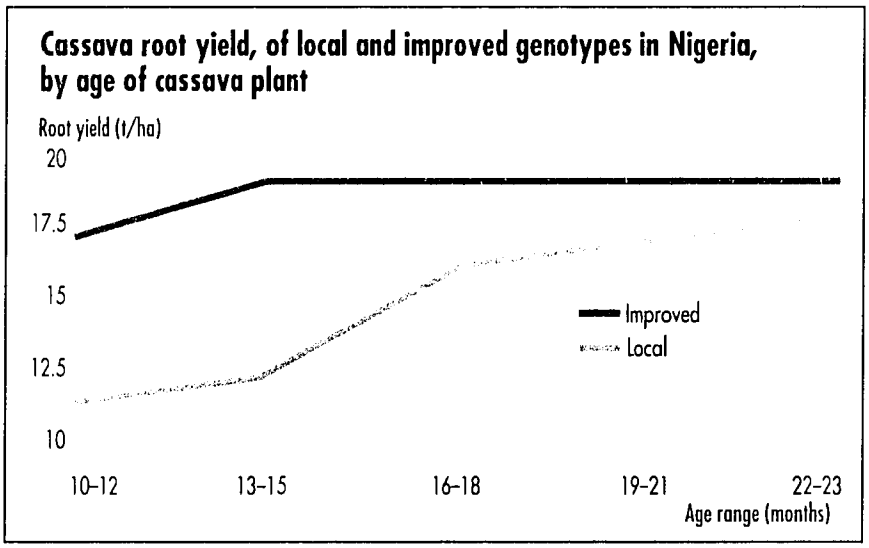
Showcase COSCA researchers view Nigeria as a test case which

Mostly light-skinned cassava roots are on display in many Nigerian markets, reflecting the growing prevalence of improved, high-yielding varieties that have spread throughout the country during the past 20 years.

MOYO BOLARIN

Farmers' adoption of productivity-enhancing practices, according to demographic pressure





shows that farmers will, when conditions permit, replace their traditional varieties with new, high-yielding varieties that meet their needs. COSCA discovered that some farmers had planted improved varieties in 90% of the Nigerian survey villages, while many or most farmers were growing them in nearly 60% of the villages. The resulting increase in the national harvest from the greater yield, it has been calculated, can feed an additional 27 million people.

High yields are the chief attraction—generally 50% more, or one and one-half times the yield of local varieties. The notion of "yield" requires some scrutiny here, however; what market-oriented Nigerian farmers like about the improved varieties is that the roots bulk or fill out faster than those of local cassava. The improved root attains its peak weight at around 15 months after planting, while the traditional type can take up to 24 months. (See graph, above.) If time in the ground were not important to farmers eager to sell their produce, they would find little to choose between the final peak weights of the two types.

Improved cassava became available in Nigeria from the mid-1970s. IITA's philosophy, as espoused by S. K. Hahn who developed most of the improved varieties being cultivated in Nigeria, was to breed varieties which would produce high yields for ordinary farmers. They could not afford to purchase much labor, pesticides, or fertilizers. IITA's improved varieties could therefore approach their full yield potential in the existing farming systems.

In 1971, IITA began to breed cassava for high root yield together with resistance to two devastating diseases: African cassava mosaic virus disease and cassava bacterial blight. By 1974, IITA and Shell Petroleum Development Co. of Nigeria Ltd. joined forces to enlist farmers to help test the improved, high-yielding cassava varieties in their fields.

Nigeria's improved cassava can be said to date from this time. Nigerian breeders, at their own research institutes, have since that time been able to select high-yielding, pest-resistant varieties adapted to local growing conditions from a range of breeding materials, in order to recommend the best varieties to be released to farmers through the extension system. Many of the improved breeding materials originated from IITA.

IITA has continued to endow cassava with other desired features and make new genotypes available to national programs throughout sub-Saharan Africa, from which selections are made of varieties suitable for local growing environments. IITA breeders are developing what some have dubbed the "super

IITA researchers have developed the so-called "super cassava" with multiples of the normal chromosome count, which enhances the possibilities of further genetic improvement of the crop.

MOYO BOLARIN

cassava:" varieties with multiples of the normal chromosome count. The additional chromosomes, generated by crossing regular cassava with wild species of the plant, enhance the possibilities of further genetic improvement of the crop.

Oil helped The spread of improved varieties throughout the country since the 1970s was possible because of Nigeria's petroleum-based economy, unique among the large African countries, and its domestic stability after the 3-year civil war ended in 1970.

Among the other countries which COSCA surveyed, Côte d'Ivoire, Ghana, and Tanzania likewise enjoyed peace and stability at the same time, but were plagued with various economic adversities. The foremost problem was poor prices for their primary exports (cocoa, coffee, cotton, sisal), which began to slide in 1975. Nigeria, on the other hand, could afford to build interstate highways and expand higher education and research institutions, all of which fueled agricultural development.

Availability of petroleum products undoubtedly promoted the development of cassava processing technology in Nigeria as well. More than two-thirds of the cassava harvest is consumed in different processed forms, which allow the staple to be stored and transported conveniently. For example, farmers in half of Nigeria's cassava-producing villages have their cassava grated by machine, a key improvement in processing *gari*, a popular form of cassava meal. By contrast, only 15% of Ghanaian villages have mechanized their grating, while none of the survey villages in other countries have done so.

In 1986, Nigeria's National Seed Service began distributing improved cassava planting materials. Within 3 years they had supplied enough materials to the state agricultural development projects (ADPs) to plant

Mechanized grating of cassava enables growers to produce more of the crop than they did when they depended on manual grating. Cassava farmers are always limited in what they can produce by their capacity to process the fresh roots, which spoil soon after harvest.

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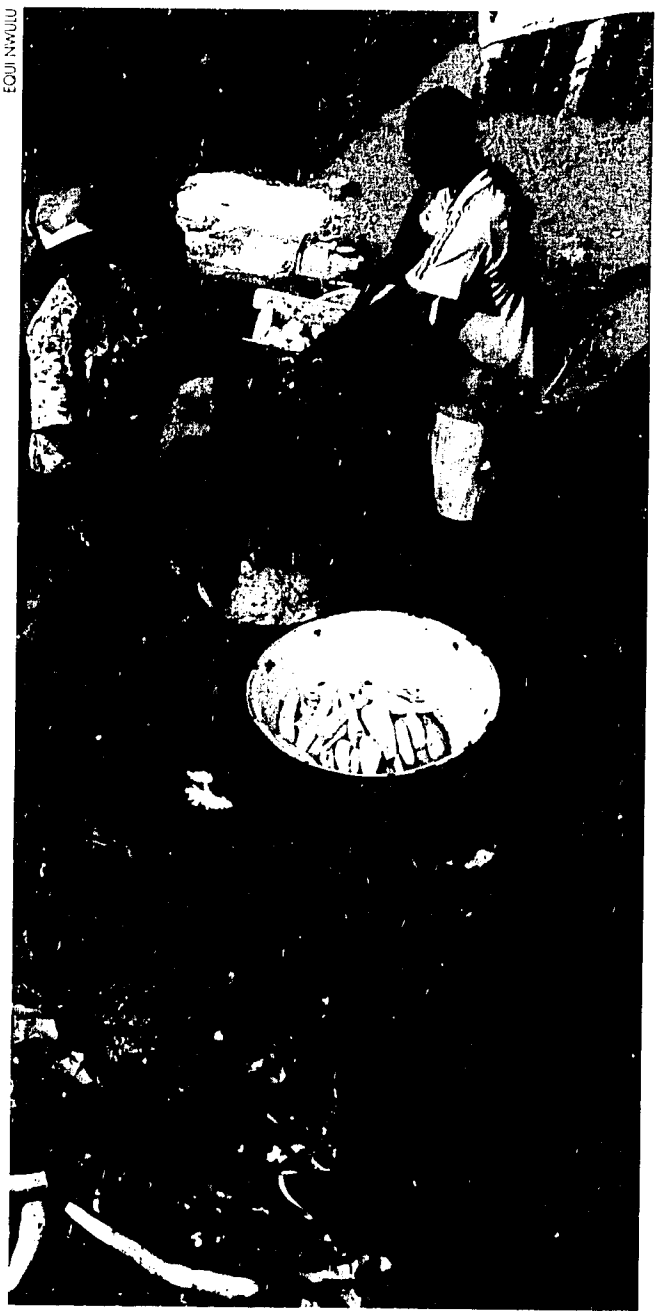


A COSCA cameo

COSCA conducted three different surveys of cassava production and processing aspects, from 1989 to 1992, in West Africa (in Côte d'Ivoire, Ghana, Nigeria), Central Africa (Zaire), and East Africa (Tanzania, Uganda). Together those countries produce about two-thirds of Africa's cassava and represent the range of climatic and economic conditions that govern cassava.

The study was expanded in 1991 to include another 9 countries, whose surveys were completed in 1992: Liberia and Sierra Leone in West Africa; Cameroon and Congo in Central Africa; Kenya, Burundi, and Rwanda in East Africa; and Malawi and Zambia in Southern Africa. In each country, one survey embraced both production and processing.

Any study of cassava must focus on the climate, population, and market system—including facilities for transportation (by road, river, railway), storage, and processing—of the area being investigated. COSCA created its own maps of climatic zones, population density, and market infrastructure of sub-Saharan Africa, based on data from standard sources.

over 9,000 hectares and support ADPs in setting up more than one-quarter million demonstration plots of IITA-improved cassava.

Farmers received improved planting materials as well from NGOs, such as religious missions, UNICEF, and the Nigerian Cassava Growers' Association. Oil companies helped in the desire to improve the welfare of local communities in areas where they were extracting and processing petroleum. Even newspapers involved themselves in the propagation of improved cassava varieties, by publicizing their usefulness and availability.

Ready? If Nigeria's experience holds for the rest of sub-Saharan Africa, yields of improved cassava varieties can similarly rise, even as populations increase and farmers reduce the time they allow their fields to fallow.

National research programs already exist which can provide for widescale multiplication and distribution of planting materials. However, they lack budgets to support field operations. Other circumstances which gave Nigerian farmers their opportunity must also prevail, to some extent—such as political stability, market infrastructure, and distribution networks that link farmers with consumers

At worst, yields need not fall below the present average levels. Changes taking place in farm communities encourage new farming practices which, at the very least, help to maintain current yields.

By overlaying the three maps, researchers could identify zones with conditions optimal for producing cassava. From the zones in the original 6 COSCA countries, 285 representative production areas were identified and one village in each was selected randomly. In each village, 3 smallholder farms (none exceeding 10 hectares) were interviewed, one each according to production level (high, medium, small).

MOYO BOLARIN

Cameroonian researchers interview cassava farmers at Kiribi in 1992 for COSCA.

EQUI NWULU

All the members of the COSCA study team must feel gratified that cassava scientists in Africa are now aware of the aspirations and problems of cassava producers, processors, and consumers; and that the scientists are seriously addressing those issues. I am convinced that cassava's roles—first and foremost as a cash crop for producing households, then as a low-cost carbohydrate source for urban consumers and as food security in vulnerable areas—will become enhanced. The potential of the crop for improving the welfare of Africa's peoples will be realized. Felix Nweke, COSCA team leader.

Tide of Battle Turns Against the Major Mite Pest

The year 1994 brought new victories in the war against cassava's biggest remaining pest in Africa, the cassava green mite. IITA's biological control program confirmed that it had established, in West Africa, another Brazilian predator of that originally South American pest and that the new predator had made remarkable inroads into the enemy's territory.

The second *Typhlodromalus* mite, *T. aripo*, joined the ranks of mite-eating mites that IITA has established in Africa. The first predacious mites to be successfully introduced in Africa were *T. manihoti* and *Neoseiulus idaeus*. (See *IITA Annual Report 1991*.)

The cassava green mite (*Mononychellus tanajoa*) causes leaf damage comparable to the effects of African cassava mosaic disease, and can reduce crop yield by one-third or more in high-yielding varieties.

MOYO BOLARIN

T. aripo survived the move from a site in its native Brazil to Benin, where it became established in the field during 1993 after a year's experimentation in rearing the species at IITA's Biological Control Center for Africa. Its fast takeoff in the field reflects precision in species selection for the African environment in which it will perform.

T. aripo appeared to establish itself and start spreading outside of Benin just as easily as inside. During 1994 it was shipped to 8 countries, to all the major compass points of sub-Saharan Africa. It became established at all locations and showed signs of spreading within the year.

In another exciting development outside Benin during the year, *T. manihoti* survived in Ghana for the fifth year since its release there in May 1990. It had spread more than 5 kilometers in all directions from its original release field near Mankesim, covering an area greater than 100 square kilometers. And in fields which the predator had colonized, populations of the cassava green mite pest werere reduced by about two-thirds.

Front-runner *T. aripo* has emerged in 1994 as the front-running predator among the 3 mites imported to fight the cassava green mite (*Mononychellus tanajoa*) from Brazil. It has shown the fastest rate of spread from field to field across broad areas of Benin.

During 1994, from its original release site to the field where it was established, thence to the farthest point it was found, *T. aripo* migrated a total distance of 30 kilometers in Benin. The cumulative total area of all release sites in Benin over which it spread is 1,500 square kilometers. Its rate of spread within a cassava plantation, once it has become established in a given field, is being studied.

Its efficacy as a predator has also been phenomenal. The population of cassava green mites in one of the release fields crashed by 90%, from nearly 100 mites per leaf to less than 10, by the end of the year. Such efficiency is good news for farmers, since damage from the cassava green mite generally amounts to a 30–50% crop loss; the recorded yield loss ranges from 10% to 80%.

T. aripo has evidently adapted itself well to prevailing conditions, wherever it has been released in the lowland humid and semihumid tropics. It inhabits the tips of cassava shoots where it is protected from extremes of temperature and humidity. In this microenvironment it survived a 6-month dry season with a severe cool period (during the "harmattan") in 1994.

Making allowance for the occurrence of settlements and roads, which hinder dispersal, the rate that *T. aripo* is spreading across West African agroecological zones (from humid forest to dry savanna) is calculated to range from 2 to 47 years, depending on the area of the zones of spreading. In each locale, the rate of spread will be influenced by the number of release sites, the

MOYO BOLARIN

The second *Typhlodromalus* mite to become established in Africa, *T. aripo* lives in the growing tips of the cassava plant (pictured at left) where it is protected from extremes in temperature and humidity.

Microscopic views show *T. aripo* in its habitat in the shoot tip (at right), and close up (below), yet hardly hint at its capacity to put an end to 20 years of devastation in Africa's cassava fields by the cassava green mite.

GEORGE GOERGEN

GEORGE GOERGEN

occurence of cassava fields, the weather, the density of the predator's prey, and many other considerations. Wherever cassava is an important crop, the message for national programs is to make as many releases of *T. aripo* as they can.

Unique IITA's use of predatory mites in the campaign against the cassava green mite is the first success of its kind anywhere—the first time that mites have been established in new tropical environments, a new continent, to conquer a mite problem of a staple food crop.

A few well-known predatory mites have been used in temperate zones of developed countries, to eliminate other mites that destroy high-value crops, in special environments such as greenhouses and orchards. But those solutions are not lasting. Often the predators must be reintroduced, according to the crop production cycle.

The achievement is based on classical principles of biological control that concern the checks and balances governing ecological stability in any environment. If a pest is introduced into a new environment and becomes a problem, its natural enemies can be found in its original home and introduced into the new environment, to reduce the problem to a scale similar to that at the origin.

From 1984, when work began on the problem, IITA's biological control program gained a great deal of knowledge about *M. tanajoa* in Africa, much more than is known about this mite species in its South American home where it is not a serious pest. That knowledge became the basis of a series of searches for natural enemies that succeeded after trials with some Brazilian and Colombian candidates.

The decade of research has been repaid beyond straightforward financial calculation: by a permanent solution to a devastating problem for millions of farmers, who have no resources to combat it otherwise.

A Project Postscript

LEGACY WITH A PROMISING FUTURE

National Cereals Research and Extension in Cameroon

From 1980 until early in 1994, Cameroon's National Cereals Research and Extension (NCRE) Project developed 14 improved varieties of maize, 7 of sorghum, and 17 of rice, and an improved local variety of millet, suitable for cultivation under different growing conditions conditions in the country. NCRE produced these new crop varieties and saw their impact in farmers' fields within 14 years, important achievements that the country has been able to share with neighboring countries with similar agricultural needs.

The Cameroonian extension system introduced these new varieties of staple crops to farmers. Since then, the country's agronomic research institute (IRA) has been

The lay of the land

Lying just north of the equator where West and Central Africa meet, Cameroon is one of Africa's environmentally most diverse countries. The span of agroecological conditions ranges from coastal humid forest to semiarid plains, from tropical montane forest and grasslands to rugged highlands that reach altitudes of 4,000 meters above mean sea level. Annual rainfall ranges from 5,000 millimeters, in the coastal forests of the southwest around Douala, to 300 millimeters in the north by Lake Chad. Of the country's 12 million people, about three-quarters lives on less than one-fifth of the land: in the coastal lowlands and western highlands. Agriculture employs from 70% to 90% of the people in each region, all but a fraction being small-scale farmers with fewer than 3 hectares of land.

IITA/NCRE

In the highlands of North West Province

responsible for annual seed maintenance and production services.

In step with cereals improvement, NCRE strengthened the technical capability of all levels of IRA staff, through training on the job, in short-term courses, and in advanced degree programs abroad. Cameroonian researchers and technicians were trained and equipped to develop take advantage of new scientific advances, enabling them on their own to or adapt technologies that farmers need in Cameroon's diverse agroecological environments.

At the start of the project there were only 7 cereals researchers in Cameroon: 2 with a PhD, 4 with the *Ingénieur agronome* degree, and 1 with an MSc. NCRE sponsored overseas training for an additional 11 PhD, 29 MSc, and 4 BSc students, as well as 105 technicians in non-degree courses. They remain the heart of the country's cereals research establishment.

Goal By 1994, NCRE was winding down, having achieved its primary goal of increasing food production, by enhancing the ability of research and extension services to develop new crop varieties and transmit them to farmers.

NCRE spent some US$64 million during its 14 years of activity. The United States Agency for International Development (USAID) gave $35.2 million in grants (55% of project expenditure) and $3.2 million (5%) in loans, while the Cameroonian government provided the rest ($25.6 million; or 40%).

By the project's end, all cereal research units were being operated by fully trained staff in functional, well-equipped experiment stations. Some $3.7 million had been spent in constructing laboratories, offices, warehouses, seed-storage cold rooms, and staff housing, to supplement the IRA infrastructure wherever required. Another $2.7 million had been spent on equipment and supplies.

IITA provided general project management with 39 international staff members (or 150 person-years) utilizing NCRE funds. Technical support in crop research came from IITA for maize; IRRI, CIAT, and WARDA for rice; and ICRISAT for sorghum and millet.

Focus NCRE focused on breeding, cultivation practices, crop protection, and economic aspects of production of the four cereals. More

Farmers in Cameroon's western highlands await transport for their maize, a variety developed by NCRE for agroecological conditions in the midaltitude zone.

MARK WINSLOW

than one-half of the research budget was devoted to crop breeding.

The agronomic and economic components were integrated in a system of liaison units placed in the principal zones. The units were responsible for diagnosing production contraints, linking station researchers with farmers, and communicating the researchers' recommendations to extension agents. They also evaluated the impact of extension activities.

Maize is the favorite cereal of Cameroonians and the most important economically, being cultivated on approximately 600,000 hectares from which is harvested about 1 million metric tons of grain yearly. NCRE created two breeding units in 1982, to tackle different production problems in lowland and highland maize-growing areas in the forest, savanna, and midaltitudes zones.

The lowland breeding program was based in the capital of Yaounde, where it developed 14 open-pollinated varieties for commercial and subsistence farmers in the northern, central, and southern parts of the country. Of those varieties, 3 were released in Chad, and 2 in the Central African Republic.

The highland breeding program was based at Bambui station in North West Province. Although this highland savanna country comprises only 10% of the land area, it contains about 25% of the population which produces 60–70% of Cameroon's maize. NCRE developed 6 varieties for highland conditions and improved another 2 that IRA had earlier released.

High and dry Sorghum and millet are produced mostly in the dry savanna of the two northernmost provinces, where low rainfall severely restricts farming possibilities. The most serious constraints for farmers are drought and the parasitic weed, *Striga hermonthica*.

NCRE developed and released 7 sorghum varieties, 2 of which show significant resistance to *Striga*. Another is drought-resistant. A local millet variety was improved and released under the name "Gouzouma".

Rice, while less important in the national diet than maize and sorghum, is growing in popularity. Locally adapted varieties are needed to compete with imported supplies. NCRE based its rice breeding program in Dschang, West Province, where it developed and released 11 varieties for irrigated conditions and 6 for upland conditions in the forest, savanna, and midaltitudes zones.

These varieties have been adopted by the parastatal cooperatives which dominate the internal rice trade. Grower and consumer acceptance has been good and NCRE's latest varieties are successfully competing with imports in local markets.

Key to success A key to NCRE's successful operations were the 4 Testing and Liaison Units (TLUs), one in each of Cameroon's main agroclimatic zones. TLU teams of economists and agronomists worked with the local extension service to test and recommend improved cultivation practices to farmers.

The TLU in the savanna highlands of North West Province identified problems in the predominant farming systems based on maize and root crops, then developed recommendations to alleviate them.

Both the TLU in South West Province's forest and highlands, and the TLU in the semiarid North Province, concentrated on characterizing the farming systems. They sought to improve station researchers' understanding of farmers' situations, so that research could address the most important problems.

The South West TLU also devised a market price recording system, which gave farmers useful information on crop prices. That enabled them to plan changes in planting and harvesting dates and to sell their produce at the best possible prices.

Evaluation of the benefits of NCRE's work was the most difficult task for TLUs, because they had no means of acquiring reliable production data on a large scale. Their own surveys provided some positive evidence, such as the 1992 adoption survey by the TLU in Center Province which found that two-thirds of local farmers had grown at least one of the new maize varieties.

Glimpses of the impact of NCRE research have also come from other official organizations. Cotton-producing SODECOTON has documented acceptance of NCRE maize varieties and recommended practices by 25,000 farmers in North Province. Average maize yields in that province tripled during the 1982–1992 decade.

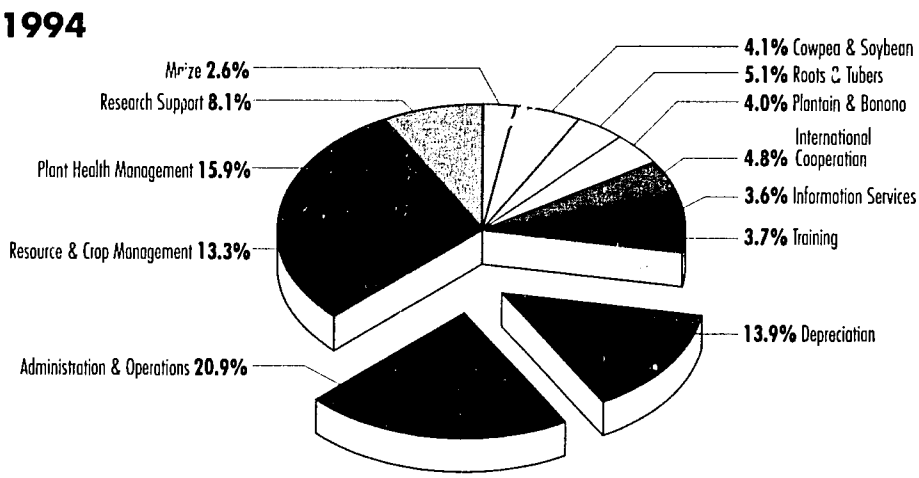
Results of a 1983–1985 survey in North West Province by MIDENO, a parastatal development agency, show that its contact farmers increased maize yields to 3.2 metric tons per hectare, from a benchmark average of about 1.8 metric tons, using an NCRE package of varieties and cultivation practices. Another survey in 1988 revealed that 46% of farmers in the province were using NCRE technologies.

A durable legacy of the project is its publications: more than 300 scientific papers and 700 extension bulletins and leaflets. They form a record of NCRE work for the benefit of researchers in Cameroon and neighboring countries that face similar problems.

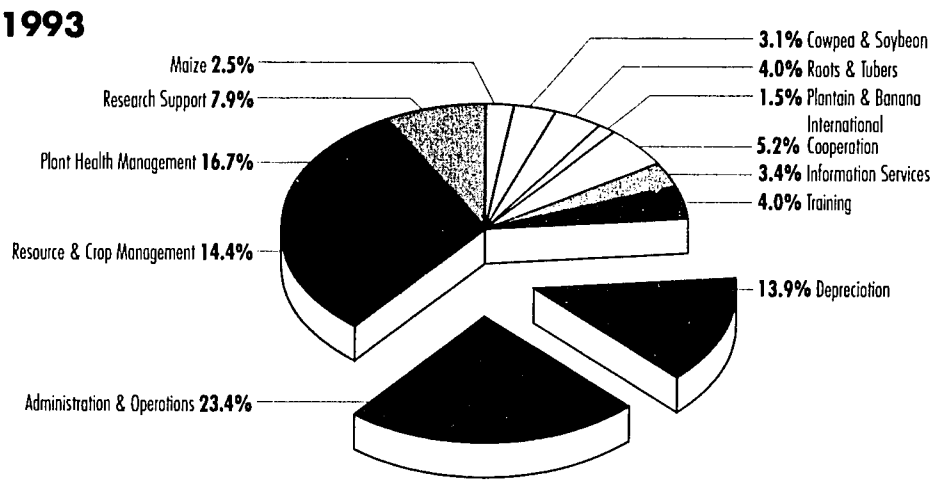
FOR THE RECORD

Major resource allocations

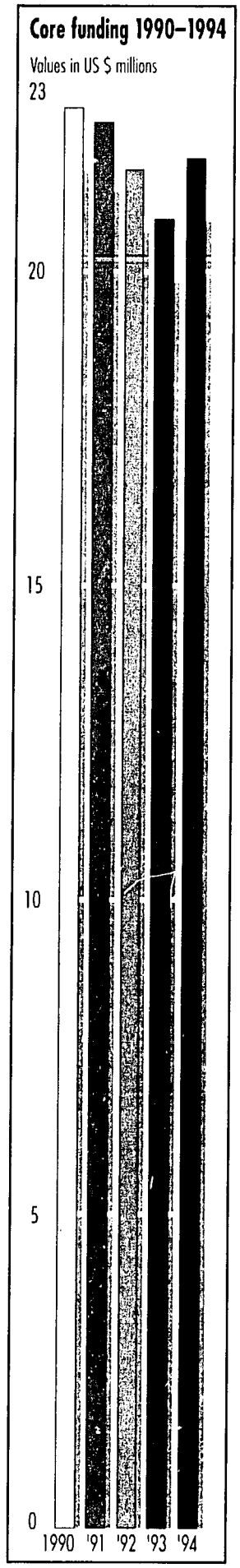
1994



1993



NOTE:
The core budget is used to fund those research-related activities essential in meeting the CGIAR objectives for developing countries.



IITA
Statement of Financial Position
31 December 1994
Expressed in US$ thousands

ASSETS	1994	1993
Current assets		
Cash and cash equivalents	24,516	14,735
Accounts receivable:		
Donors	2,352	5,428
Others	1,390	1,052
Inventories	1,135	1,125
Prepaid expenses	941	933
Other assets	140	265
Total current assets	30,474	23,538
Fixed assets		
Property, plant and equipment	65,111	62,817
Less: accumulated depreciation	35,181	32,736
Total fixed assets—net	29,930	30,081
Total assets	60,404	53,619
LIABILITIES AND FUND BALANCES		
Current liabilities		
Accounts payable and other liabilities	4,123	4,529
Accrued salaries and benefits	5,019	3,975
Payments in advance—donors	8,937	4,863
Total current liabilities	18,079	13,367
Net assets		
Capital invested in fixed assets	29,930	30,081
Capital fund	4,796	4,530
Operating fund	7,599	5,641
Total net assets	42,325	40,252
Total liabilities and net assets	60,404	53,619

IITA
Statement of Activity
31 December 1994
Expressed in US$ thousands

REVENUE	1994	1993
Grants	31,569	34,086
Investment income	652	323
Total revenue	32,221	34,409
EXPENSES		
Research programs	19,620	22,763
Conferences and training	2,303	2,114
Information services	778	754
General administration	2,116	3,088
General operations	2,429	2,710
Depreciation	3,017	2,991
Total expenses	30,263	34,420
Excess of revenue over expenses	1,958	(11)

IITA
Statement of Cash Flows
31 December 1994
Expressed in US$ thousands

	1994	1993
Cash flows from operating activities		
Excess of revenue over expenses	1,958	(11)
Adjustments to reconcile net cash		
Provided by operating activities:		
Depreciation	3,017	2,991
Gain on disposal of assets	115	116
Decrease (increase) in assets:		
Accounts receivable—donors	3,076	1,465
Accounts receivable—others	(338)	490
Inventories	(10)	(84)
Prepaid expenses	(8)	(192)
Other assets	125	13
Increase (decrease) in liabilities		
Accounts payable and other liabilities	(406)	469
Accrued salaries and benefits	1,044	500
Payments in advance—donors	4,074	(2,957)
Total adjustments	10,689	2,811
Net cash provided by operating activities	12,647	2,800
Cash flow used in investment activities:		
Acquisition of fixed assets:	(2,866)	(2,128)
	9,781	**672**
Net increase in cash and cash equivalents		
Cash and cash equivalents: End of year	24,516	14,735
Beginning of year	14,735	14,063
Increase in the year	**9,781**	**672**

IITA
Donors 1994
Expressed in US$ thousands

DONORS	Core Funding	Complementary Project Funding
Austria	150	214
Belgium	1,340	170
BMZ (Germany)	1,120	597
Canada	1,196	124
China	10	–
Commission of the European Communities	229	243
Denmark	644	152
Ford Foundation	–	3
France	322	88
Gatsby Charitable Foundation		65
India	25	–
International Centre for Research in Agroforestry	–	90
International Development Research Centre	–	760
International Fund for Agricultural Development	–	62
International Institute of Biological Control	–	473
Italy	300	294
Japan	3,778	–
Korea, Republic of	50	–
Netherlands	1,121	59
Nigeria	23	–
Norway	891	–
Overseas Development Administration (UK)	–	14
Rockefeller Foundation	–	320
Sasakawa Foundation	–	70
Sweden	253	–
Switzerland	637	371
United Kingdom	614	–
United Nations Development Programme	–	1,827
United States Agency for International Development	3,745	3,404
University of Hohenheim	–	116
World Bank	5,365	–
Other Miscellaneous Contributions	–	159
Closed Projects	–	81
TOTAL	21,813	9,756

Inventory of Research Projects

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Crop Improvement Division				
GRAIN LEGUMES				
Cowpea improvement for cereal-based cropping systems of northern Guinea savanna, Sudan savanna, and Sahel	core, JIRCAS, ODA	IAR, INRA, INRAN, ABU, ICRISAT, Long Ashton, VSO, U Reading, JIRCAS	var. sites, W&C Africa, Nigeria, Benin, UK, Japan	continuous
Cowpea improvement for broad-based adaptation to the tropics	core	NARS in W&C Africa, Latin America, Asia	var. sites, W&C Africa, Latin America, Asia	continuous
Nonconventional breeding for insect resistance	core	—	Nigeria	1994–
Cowpea international trials	core	NARS, Africa, Asia, Latin America	Africa, Asia, Latin America	continuous
Nationally coordinated research on cowpeas	Nigeria	IAR	Nigeria	1975–
Soybean utilization for West Africa (Phase III)	IDRC	IAR&T, UNN, NAERLS, NCRI	Nigeria	1994–1998
•Dissemination of soybean utilization and impact assessment	IDRC	FRI, LBSA-FAST	Ghana, Côte d'Ivoire	1994–1998
•Dissemination of soybean processing and utilization technologies	UNICEF		Nigeria	1995
Soybean improvement for the moist and midaltitude savannas				
•Soybean breeding	core	—	var. sites, W&C Africa	1977–
•Studies on promiscuous nodulation in soybean	NiFTAL/core	NiFTAL	Nigeria	1992–
Soybean international trials	core		var. sites, Africa	1979–
Nationally coordinated research on soybean	Nigeria	NCRI, IAR, IAR&T	Nigeria	1980–
Development of cowpea and soybean for Ghana	CIDA	CRI	Ghana	1985–1997
MAIZE				
Maize improvement for the northern Guinea savanna				
•*Striga* resistance	core, Winrock	IDESSA, IAR	Nigeria, Côte d'Ivoire	continuous
•Intermediate-maturing populations	core	IDESSA	Côte d'Ivoire	continuous
•Inbreds and hybrids	core	Premier Seed, UAC	Nigeria	continuous
•Nitrogen-use efficiency	core, GTZ	UI, U Hanover	Nigeria, Germany	continuous
Agroecological adaptation				
•Reciprocal recurrent selection	core	IAR&T	Nigeria	continuous
•Adaptation to specific niches—early, extra-early, midaltitude, humid forest	core	WECAMAN, UTC	Nigeria, Côte d'Ivoire	continuous
•Downy mildew resistance	core	IAR&T, Fed. College of Agric.	Nigeria	continuous
•Fitting varieties to environments	core	—	Nigeria	continuous
Postharvest research				
•Maize quality and utilization	core, WI, Guinness Nigeria plc	IAR&T, U Benin (Nigeria), IER, Ministry Rural Dev.	Nigeria, Mali, Benin	continuous
Collaboration with NARS				
•International trials	core, USAID, NARS	WECAMAN, var. NARS	Nigeria, Côte d'Ivoire	continuous
•Training	core, GTZ, WI	UI, U Hanover, U Hassan II, U Ghana	Nigeria, Germany, Morocco, Ghana	continuous
•Links with seed companies, NGOs, and NARS in Nigeria	core	SAA, ADPs, seed companies	Nigeria	continuous
PLANTAIN/BANANA				
Musa breeding				
•Developing *Musa* breeding strategy	core	USDA/ARS, KUL	Nigeria	1992–
•Breeding plantains for West and Central Africa	core/BADC	INIBAP, FHIA, CRBP, KUL, NIHORT, CRI, IDEFOR, IRAZ, UNBRP, ICIPE, other NARS	Cameroon, Nigeria, Uganda, Ghana, Côte d'Ivoire, Kenya, Malawi, Burundi, Zanzibar	1987–
•Breeding bananas for east and southern Africa	core/USAID	NARS, IRAZ	Nigeria, Uganda	1992–
•Breeding for resistance/tolerance to biotic and abiotic stresses	core	USDA/ARS, KUL	Nigeria, USA	1987–
•Biotechnology for plantain and banana improvement	core	U Birmingham, USDA/ARS	Nigeria, USA, UK	1983–
Postharvest biology and technology				
•Postharvest research in *Musa*	core	NARS	Uganda, Ghana, Nigeria	1991–
Genotype-by-cropping-system interaction				
•*Musa*-oriented agronomy	core	NARS	Nigeria	1980–

Project title	Funding Sources	Cooperating Institutions	Location	Duration
ROOT AND TUBER CROPS				
Germplasm enhancement of cassava	core, CIAT, DANIDA	CIAT, EMBRAPA, NARS, ANU, RVAU	Colombia, Brazil, Nigeria, Australia, Denmark	continuous
Cell/tissue culture and post-flask management	core	NARS	Nigeria, var. African countries	continuous
Adaptation to lowland agroecologies	core	NARS	var. sites in W&C Africa	continuous
Adaptation to midaltitude agroecologies				
•Development of broad-based segregating populations	core, USAID	NARS	Nigeria, Uganda	1990–
Expansion of cassava utilization	core, BADC/FDC	KUL, UI, ILRI	Belgium, Nigeria	continuous
Collaboration with NARS and ESARC				
•Germplasm distribution and testing	core, USAID	NARS, ESARC	Nigeria, Uganda, var. sites, SSA	continuous
•International collaborative trials	core, NARS	NARS	var. sites, W&C Africa	continuous
•Nationally coordinated research trials on cassava	Nigeria	NRCRI, NSS	Nigeria	continuous
Research and development	core, NARS	NARS	var. sites, W&C Africa	continuous
Germplasm enhancement of yam	core	NARS	var. sites, W&C Africa	continuous
Cell/tissue culture and post-flask management	core, ODA, Italy	Wye College, SARI U Ghana	UK, Ghana, Nigeria	continuous 1992–1995
Agroecological adaptation of yam	core	NARS	var. sites, SSA	continuous
BIOTECHNOLOGY RESEARCH				
Nonconventional approaches to crop improvement				
•Cowpea plant regeneration and genetic transformation for resistance to insects	core/Italy	U Naples, Purdue U, Auburn U	Italy, USA	1989–
•Cowpea transformation and development of virus resistance	GCF	JIC	UK	1994–1996
•Biotechnology for cowpea improvement	Belgium	Gent U	Nigeria	1992–1995
Molecular mapping				
•Genetic map of yams	GCF	JIC	Nigeria	1994–1998
•Molecular mapping of *Vigna*	GCF	JIC	Nigeria	1994–1996
Molecular diagnostics				
•Variation in yam mosaic virus	GCF	NRI	UK	1994–1996
•Viruses of *Dioscorea alata*	GCF	Horticulture Research Intl.	UK	1994–1996
•Banana streak virus	GCF	JIC	UK	1994–1996
GENETIC RESOURCES				
Conserving biodiversity	core/Italy	African NARS, IPGR	SSA countries	continuous
Germplasm characterization, documentation, and distribution	core/Italy	PGI	Nigeria/Italy	continuous
Studying genetic diversity	core/Italy	PGI	Nigeria/Italy	continuous
Plant Health Management Division				
CASSAVA				
•Studies on yield formation and interactions between the cassava plant, its pests, and the climate throughout the entire growth cycle	core	—	Benin, Nigeria	1982–1994
•Characterization of aspects of the biology and key interactions in the surrounding agroecosystem of *M. tanajoa*	core, UNDP	EMBRAPA, CIAT, U Amsterdam	Benin, Brazil, Central African Republic, Cameroon, Colombia, Ghana, Netherlands, Nigeria, Rwanda, Senegal, Sierra Leone, Uganda, Zaire, Zambia,	1983–1997
•Effects of farming practices on the biological control of the cassava mealybug	core	U Leiden, ETH	Benin, Ghana, Guinea, Kenya, Malawi, Tanzania, Zambia	1988–1995
•Epidemiology of African cassava mosaic virus	core, ODA	NRI, U Reading	Nigeria	1992–1994
•Epidemiology of cassava bacterial blight and its effect on yield in five acroecological zones	BMZ	U Benin, U Ibadan	Benin, Nigeria	1993–1995
•Genetic, biochemical, and pathological characterization of *Xanthomonas campestris* pv. *manihotis* strains from 5 African countries and Latin America	BMZ	U Gottingen, Plant Protection Service, Wageningen, ORSTOM, Montpellier	Benin, Germany, Netherlands, France	1993–1995
•Collection, characterization, and biological control of root and stem rot pathogens of cassava	BMZ, UNDP	IRA, Ekona, NRCRI	Benin, Cameroon, Ghana, Nigeria	1993–1995
YAM				
•Biology and control of yam anthracnose	core	NRI/U Reading	Nigeria	1992–1995

Project title	Funding Sources	Cooperating Institutions	Location	Duration
MAIZE				
•Analysis of the maize ecosystem with focus on the most important lepidopterous pests in Africa	core, IFAD	ICIPE, Texas A&M, CABHIE, Simon Frazer U, U Reading, ICRISAT, NARS, WARDA, CIMMYT	Benin, Côte d'Ivoire, Ghana, Malawi, Nigeria, Cameroon, Niger, Guinea, Uganda	1989–1995
•Biology and epidemiology of *Striga* spp.; development of improved resistance screening techniques; improvement of resistance levels; studies on biological control, agents, development of agronomic practices for *Striga* control; development of predictive models for control strategies	core, BMZ, USAID	Old Dominion U, U Hohenheim, IAR, ABU, CIMMYT, ICRISAT, U Nairobi, Dupont Co., NCRI, U Bonn, U Gent, U Nantes, Tech. U Braunschweig	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Nigeria, Togo	1989–1995
•Characterization of maize pathogens	core	IRA, IAR&T, NARO	Cameroon, Nigeria, Uganda	1992–1994
•Biology of leafhopper vectors of maize streak virus	core	NRI	Nigeria, Uganda	1989–1995
•Downy mildew biology and control	core, FAO, CIBA	IAR&T, ADPs U Maiduguri, UI	Nigeria	1993–1995
•Ecological studies on the introduced larger grain borer in stored maize and cassava and in the surrounding habitats	BMZ, DANIDA, EAP	INIFAP, CP, CIMMYT, BBA, EAP, U Göttingen, U Hannover, U Ghana	Benin, Honduras, Ghana, Mexico	1988–1996
•*Aspergillus flavus* prevalence and toxicity pattern	WI, BMZ	U Berlin, UI, Fed. U Tech. Akure	Benin, Germany, USA, Nigeria	1992–1995
COWPEA				
•Feasibility study for the introduction of ecologically and economically sound pest management strategies adapted to subsistence farming systems	core, SDC	ETH, U Laval, MARDI, ABU, ILRI, AUW, Purdue U	Benin, Burkina Faso, Malaysia, Nigeria, Niger	1987–1996
•Studies on virus diseases of cowpea	core	AUW, IRA	Cameroon, Mozambique, Nigeria	1990–1994
•Studies on postharvest insect pests of cowpea	core	Purdue U	Nigeria, USA	1990–1995
•Characterization of major pests and diseases in the northern Guinea and Sudan savannas	core	IAR	Nigeria	1991–1994
•Screening cowpea varieties for resistance to pathogens in the dry savanna	core	INRAN	Niger	1991–1994
•Collection and genetic, biochemical, and pathological characterization of *Xanthomonas* strains, *irratants* of cowpea bacterial blight and pustute from six African countries	BMZ	Dep. Sanidade Vegetal, Maputo, INERA, IAR, ABU, ORSTOM, U Gottingen	Benin, Mozambique, Burkina Faso, Niger, Nigeria, Cameroon, France, Germany	1993–1995
SOYBEAN				
•Yield loss from frogeye leaf spot on farmers' fields	core	CUSO	Nigeria	1994–1995
•Epidemiology and control of red leaf blotch	core, FAO	U Jos, Zambia Min. Agric., Res. Branch	Nigeria, Zambia	1994–1996
•Biology of red leaf blotch	core	U Jos	Nigeria, Zambia	1991–1995
PLANTAIN AND BANANA				
•Biology of *Mycosphaerella fijiensis*, causal agent of black sigatoka disease	core	—	Nigeria	1991–1994
•Studies on virus diseases of plantain	core	U Minnesota	Nigeria, Benin, Ghana	1993–1996
•Screening plantain and cooking banana for resistance to black sigatoka	core	FHIA, INIBAP	Cameroon, Nigeria	1991–1996
•Effects of ecological factors and agronomic practices on the pest status of black sigatoka, banana weevil, and nematodes in highland bananas and plantain	RF, BMZ	SDC, IIBC, CIAT, Agriculture Canada, U Laval	Benin, Nigeria, Uganda, Ghana	1989–1995
•Studies on postharvest insect pests of maize	core, ODA	UNB, NRI	Benin, Nigeria, UK	1989–1995
SEED HEALTH				
•Development of improved detection methods for seedborne pathogens	core	NPQS	Nigeria	1994–1996
•Studies of seedborne microflora of IITA mandate crops	core	—	Nigeria	1994–1996
BIOLOGICAL CONTROL				
Mango mealybug				
•Biological control of the mango mealybug by the introduced parasitoid, *Gyranusoidea tebygi*: quantification of impact in different ecological conditions	SDC	U Leiden	Benin, Conakry, Côte d'Ivoire, Gabon, Ghana, Guinea, Nigeria, Sierra Leone, Zaire, IAR	1987–1995

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Water hyacinth				
•Rearing, release, and monitoring of *Neochetina eichhorniae*, a beetle feeding on water hyacinth	BMZ	CSIRO, IIBC	Benin	1991–1995
Biorational control of acridid pests				
•Joint biological control project aganst locusts and grasshoppers using the fungus *Metarhizium flavoviride*	CIDA, ODA, DGIS, SDC	DFPV, IIBC, plant protection services of Benin, Niger, Senegal, Mali, Burkina Faso,	Benin, Niger, Mali, UK Burkina Faso, Senegal	1990–1995
Spiralling whitefly				
•Biological control of spiralling whitefly, a polyphagous pest	FAO	IIBC	Benin, Togo, Ghana, Nigeria	1994–1995
Faunistic and systematic studies				
•Development of insect museum to support ecosystems analysis	Austria	IIBC	Benin, Cameroon, Nigeria	1991–
Development of national biological control programs	BMZ, Austria	NARS	25 SSA countries	1990–1996
Resource and Crop Management Division				
HUMID FOREST ZONE				
Characteristics and dynamics of humid forest zone agroecologies	var.	AB, ASB, Cornell U, ICRAF NARS, Tiger Project (UK) U Queensland	Cameroon, Nigeria	1994–1998
•Strategies for humid forest zone development	core, ASB	ASB, ICRAF, IFPRI, IRA	Cameroon	1994–1998
•Integrated soil, crop, and vegetation management practices for the humid forest zone	core	AB, ASB, Cornell U, ICRAF, KUL, NARS, TSBF, U Queensland, U Reading	Cameroon, Ibadan, Onne, W&C Africa	1994–1998
•Management options for the crop and vegetation component of production systems				
Sustainable production systems for the humid forest zone	core	AB, ASB, ICRAF, ILRI, KUL, NARS, U Queensland, Tiger project, WARDA	Cameroon, Onne, Rokupr, Sierra Leone	1994–1998
MOIST SAVANNA ZONE				
•Diagnosis and impact assessment	core	AFNETA, ATB, IAR, NARS	W&C Africa	1994–1998
•Soil productivity management	core, Belgium GTZ	AFNETA, GTZ, IAR, IDESSA, ISF, KUL, Michigan State U, UI	Benin, Nigeria	1994–1998
•Vegetation management for plant residue and control	core, AGCD DGIS	CIRAD, ILRI, NARS ORSTOM	Benin, all MSZ in West Africa Cameroon, Côte d'Ivoire, Nigeria, Togo (all W African moist savanna)	1993–1998
•Production systems for the moist savanna zone	core	CIAT, CIMMYT, CIP, ICRISAT, ILRI, NARS, WARDA	—	
•Technology development for hydromorphic soils in the moist savanna zone	core	NARS, WARDA	—	
RESEARCH SUPPORT UNITS				
Postharvest Engineering	core, SSA	NARS —	Benin, Ghana, Nigeria, Togo	1993–
Alley Farming Network for Tropical Africa (AFNETA)	core, IDRC	ICRAF, ILRI, NARS	var. countries in Africa	1993–1996
Analytical Services	core	NARS	Ibadan	1993–1996
Collaborative Study of Cassava in Africa (COSCA)	core	CIAT, ICHU, NARS, NRI, RF	Ibadan	to 1997
Agroecological Studies	core	NARS, var. IARCs	SSA	1992–
International Cooperation Division				
NCRE: Development of institutional capacity for research on cereals and facilities for transmitting research results to farmers (Phase III)	USAID	IRA	Cameroon	1986–1994
SADC: Cowpea Research Project: Development of cowpea production in SADC countries	EEC	Angola, Botswana	INIA, Lesotho, Mozambique, Namibia, Swaziland, Malawi, Tanzania, Zambia, Zimbabwe,	1990–1994
SARRNET: Development of improved cassava and sweet potato varieties for sustainable production in Southern Africa	USAID, IDRC	Angola, Malawi, Mozambique, Namibia, Rwanda, Sudan, Tanzania, Uganda, Zimbabwe	Malawi	1993–1998

Project title	Funding Sources	Cooperating Institutions	Location	Duration
AFNETA: Applications of alley farming as a basis for sustainable farming systems	CIDA, DANIDA, IDRC, IFAD, USAID	Burkina Faso, Benin, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Liberia, Malawi, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, Uganda, Zaire, Zambia	Nigeria	1989–1996
EARRNET: Development of cassava varieties for sustainable production in East Africa	USAID, IDRC	Burundi, Kenya, Madagascar, Rwanda, Uganda	Uganda	1993–1995
On-farm adaptive research for cassava, yam, rice, maize, cowpeas, and soybean in tropical Africa	EEC	Benin, Burkina Faso, Cameroon, Chad, Congo, Côte d'Ivoire, Equatorial, Guinea, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Nigeria, São Tome & Principe, Senegal, Sierra Leone, Togo, Zaire	Nigeria	1990–1994
Utilization of cassava flour in baking bread	AGCD	KUL, RVAU	Nigeria	1992–1994
Regional research project on maize and cassava	France, CGIAR	Benin, Cameroon, Congo, Gabon, Guinea, Nigeria, Togo	Nigeria	1992–1994

IITA improved germplasm releases

Country	Crop	Breeding line/variety
Angola	Cowpea	TVx 3236
	Maize	TZMBR-W
Belize	Cowpea	VITA-3
Benin Republic	Cowpea	VITA-4, VITA-5, IT81D-1137, IT82E-16, IT82E-32
	Cassava	TMS 30572, TMS 30572A, TMS 4(2)1425
	Maize	TZB-SR, 43-SR, DMR-ESR-W, 30-SR, 9 021-18 (Oba super 1), 8644-27 (Oba super 2)
Bolivia	Cowpea	IT82D-442, IT82D-889
Botswana	Cowpea	ER-7, TVx 3236
Brazil	Cowpea	4R-0267-01F, VITA-6, VITA-3, VITA-7, TVx 1836-013J
Burkina Faso	Cowpea	TVx 3236, VITA-7 (KN-1)
	Maize	EV 8422-SR, EV 8430-SR, EV 8431-SR
Burma	Cowpea	VITA-4 (Yezin-1)
Burundi	Cassava	TMS 40160/3, TMS 40160/1
Cameroon	Cowpea	IT81D-985, IT81D-994, TVx 3236
	Maize	TZB-SR, TZPB-SR, TZB derivation, DMR-ESR-Y, Kasai-SR, Suwan 1-SR, 8321-18, 8556-6
	Cassava	TMS 8034, TMS 8017, TMS 8061, TMS 82516
Central African Republic	Cowpea	VITA-1, VITA-4, VITA-5, TVx 1948-01F, Vita-7
	Maize	TZSR-W-1, TZSR-Y-1, TZB-SR
Chad	Cowpea	IT81D-994
Colombia	Cowpea	IT835-841
Congo	Maize	8644-27
El Salvador	Cowpea	TVx 1836-013J, VITA-3, VITA-5
Equador	Cowpea	VITA-3
Ethiopia	Maize	Gusau 81 TZB*, Gusau TZB-SR*, 8322-13,
	Cowpea	TVx 1977-01D
Egypt	Cowpea	TVu 21, IT82D-716, IT82D-709
Fiji	Cowpea	VITA-1, VITA-3
Gabon	Cassava	CIAM 76-6, CIAM 76-7, CIAM 76-13, CIAM 76-33, TMS 42025, TMS 30555, TMS 30337, TMS 40160, TMS 4(2)1425
	Maize	TZPB, TZ sweet
Gambia	Cassava	TMS 60142
	Cowpea	IT84S-2049 (Soso royo)
Ghana	Cowpea	IT82E-16, IT83S-728-13, IT83S-818, TVx 1843-IC, TVx 2724-OIF, IT84S-2049 (Soso Royo)
	Maize	49-SR, Pool 16-SR, 43-SR, QPM Pop63-SR
	Cassava	TMS 30572*, TMS 50395*, TMS 4(2)1425*
	Soybean	TGx 297-192C, TGx 306-036C, TGx 888-49C, TGx 536-02D, TGx 297-10F, TGx 813-6D
Guinea	Cowpea	IT85F-867-5 (Pkoku Togboi), IT85F-2805, IT835-990, IT83D-340-5, IT81D-897 IT82E-16, IT875-1463
	Cassava	TMS 30572
	Maize	TZSR-Y-1, EV28-SR, DMR-ESR-Y
Guinea Bissau	Cassava	TMS 4(2)1425, TMS 60142
Guatemala	Cowpea	VITA-3
Guyana	Cowpea	ER-7, TVx 2907-02D, TVx 66-2H, VITA-3
Haiti	Cowpea	VITA-5
India	Cowpea	VITA-4, TVx 1502
	Maize	TZi lines as parents
Jamaica	Cowpea	VITA-3, ER-7
Korea, Rep. of	Cowpea	VITA-5
Korea, Rep. of	Cowpea	VITA-5
Liberia	Cowpea	IT82D-889, TVx 3236, VITA-5, VITA-4, VITA-7
	Cassava	CARICASS 1, CARICASS 2, CARICASS 3
Mauritius	Maize	TZSR-Y-1, TZSR-W-1
	Cowpea	TVx 3236

* Released in 1993/94

Country	Crop	Breeding line/variety
Mali	Maize	Suwan-1SR
Mozambique	Cowpea	IT82E-18
	Cassava	TMS 30001, TMS 30395, TMS 42025
	Maize	Matuba (DMR-ESR SEMOC-1)
Nepal	Cowpea	IT82D-889, IT82D-752
Nicaragua	Cowpea	VITA-3
Niger	Cassava	TMS 4(2)1425
	Maize	TZESR-W
Nigeria	Cowpea	IT84S-2246, TVx 3236, IT82E-60, IT81D-994, IT86D-719, IT86D-721, IT90K-76, IT89KD-374, IT88D-867-11
	Cassava	TMS 50395, TMS 30572, TMS 30001 TMS 4(2)1425, TMS 30555, TMS 91934, TMS 82/00058, TMS 81/00110, TMS 81/00661, TMS 90257, TMS 84537
	Soybean	TGx 849-313D, TGx 1019-2EN, TGx 1019-2EB, TGx 1448-2E, TGx 536-02D, TGx 306-036C, TGx 1485-ID, TGx 1440-IE
	Maize [open-pollinated]	TZPB, 096EP6 TZMSR-W, TZSR-Y, TZSR-W, TZEYR-W, TZESR-Y, DMR-LSR-W, DMR-LSR-Y, DMR-ESR-W, DMR-ESR-Y, TZB-SR, TZPB-SR, EV 49-SR, POOL 16-SR, Suwan 1-SR, EV43-SR
	Maize [hybrid]	8321-18, 8321-21, 8322-3, 8322-13, 8329-15, 8341-5, 8425-8, 8428-19,8434-11, 8505-2, 8505-3, 8505-4, 8505-5, 8505-13, 8644-27, 8644-31, 8644-32, 8516-12, 8535-23, 8556-6, 9021-18 STR, 9022-13 STR,
	Cooking banana	Cardaba
Pakistan	Cowpea	VITA-4
	Maize	TZi18, TZi25 as parents
Panama	Cowpea	VITA-3
Paraguay	Cowpea	IT86D-1010, IT87D-2075 IT87D-697-2, IT87D-378-4
Peru	Cowpea	VITA-7
Philippines	Cowpea	IT82D-889
Rwanda	Cassava	TMS 30572, Gakiza (UYT bulk 1977), Karana (PYT bulk 1977)
	Maize	TZMSR-W
Sao Tome & P.	Maize	TZSR-Y-1, TZSR-W-1
Senegal	Cowpea	TVx 3236
Seychelles	Cassava	SEY 14, SEY28, SEY32, SEY41, SEY52
Sierra Leone	Cowpea	TVx 1999-01E, IT86D-1010, IT86D-721, IT86D-719, IT82E-32, TVx 3236, Vita-3
	Maize	TZSR-Y-1, EV 28-SR, DMR-ESR-W
	Cassava	ROCASS 1, ROCASS 2, ROCASS 3, NUCASS 1, NUCASS 2, NUCASS 3, 80/40
Somalia	Cowpea	TVx 1502
	Maize	DMR-ESR-W
Sudan	Maize	DMR-ESR-W, DMR-LSR-W, Gusau TZB
Sri Lanka	Cowpea	IT82D-789, IT82D-889, TVx 309-01G, TVx 930-01B
Swaziland	Cowpea	IT82E-18, IT82E-32, IT82E-71, IT82D 889
Tanzania	Cowpea	TK-1, TK-5, IT82D-889
	Maize	DMR-ESR-W
Thailand	Maize	TZi 18, TZi 25 as parents
Togo	Cowpea	VITA-5, TVx 3236
	Maize	49-SR, 8322-13 STR, TZESR-W
	Cassava	TMS 4(2)1425, TMS 30572
Uganda	Cowpea	TVx 3236, IT82E-60
	Cassava	TMS 30572 (as Migyera)*, TMS 60142 (as Nase 1)*, TMS 30337 (as Nase 2)*
	Soybean	selection from IITA breeding lines (Nam 2)
	Maize	Acr 83 TZMSR-W, 8535-23, 8556-6
Venezuela	Cowpea	VITA-3
Vietnam	Maize	TZi 25 as parent
Yemen	Cowpea	TVx 3236, IT82D-789, VITA-5
Yemen, South	Cowpea	VITA-5, VITA-7
Zaire	Cowpea	IT82E-18, Vita-6, Vita-7
	Maize	83TZMSR-W, Ik 83 TZSR-Y-1, DMR-ESR-W
	Soybean	TGx 814-76D, TGx 849-294D
	Cassava	Kinuani, F100, TMS40230/3
Zambia	Cowpea	TVx 456-01F, TVx 309-1G
	Cassava	LUC 133

* Released in 1993/94

IITA Publications 1994

Afnetan. Newsletter of the Alley Farming Network for Tropical Africa. Vol. 6 nos. 1, 2 (bilingual; English and French).

Biological and integrated control of highland banana and plantain pests and diseases. C.S. Gold and G. Gemmill, eds. Proceedings of a Research Coordination Meeting. 455 pp. [1993]

Bulletin d'information manioc. Vol. 18 no. 1.

Bulletin des plantes tropicales à racines et tubercules. Vol. 8 no. 1.

Dealing with the issues of our times. 15 pp.

Face aux défis actuels. 15 pp.

IITA annual report 1993.

IITA rapport annuel 1992.

IITA research. Nos. 8, 9.

MusAfrica: The plantain and banana newsletter published by the International Institute of Tropical Agriculture. Nos. 4, 5.

Probleme unserer Zeit. 15 pp.

RALASV. Bulletin du Réseau africain des laboratoires d'analyse de sols et des végétaux. No. 3.

La recherche à l'IITA. Nos. 5, 6.

SPALNA: Newsletter of the Soil and Plant Analytical Laboratories Network of Africa. No. 3.

Stem and ear borers of maize in Ghana. S. Gounou et al. Plant Health Management Research Monograph No. 4. 23 pp.

Tropical root and tuber crops bulletin. Vol. 8 no. 1.

Tropical root crops in a developing economy. F. Ofori and S.K. Hahn, eds. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops. (IITA/ISTRC/Government of Ghana copublication.)

Graduate research completed at IITA during 1994

Degree sought	Country of origin	University (U)	Sponsor	Name	M/F	Research topic
Crop Improvement						
PhD	Cameroon	Washington State U, USA	RF	Ndi, E. E.	M	Cassava: Relating physicochemical and biochemical properties to end-use quality
PhD	Uganda	U Ibadan, Nigeria	FF	Ssemakula, N. G.	F	Expression, mechanisms and genetics of soybean resistance to *Nezara viridula* (L.) and *Spodoptera littoralis* (Biosd.)
PhD	Zaire	Université catholique de Louvain, Belgium	Self/ AGCD	Kunda, K. N.	M	*Matière organique du sol et cinetique de mineralisation de la matière organique azotée du sol dans les jachères naturelles et dans les parcelles cultivées*
MSc	Nigeria	U Ibadan, Nigeria	Self	Mohammed, A.	M	Studies of yield potential of varieties of maize in the savanna ecology of Nigeria
MSc	Cameroon	U Ibadan, Nigeria	RRPMC	Manga, G. B.	M	Sprouting and establishment of cassava
MSc	Cameroon	U Ibadan, Nigeria	RRPMC	Woumane, M.	M	Cassava (*Manihot esculenta* Crantz) selection for adaptation to inland valleys
MSc	Nigeria	U Ibadan, Nigeria	Self	Ezeji, T.	M	Production and preservation of tofu with *Aframomum danielli*
MSc	Nigeria	U Ibadan, Nigeria	Self	Chikere, A.	M	Preservation of soymilk with extracts from *Aframomum danielli* and *Allium sativum*
MSc	Germany	U Hannover, Germany	GTZ	Collet, L.	M	Study on genotypical difference in the nitrogen uptake of maize cultivars
MSc	Belgium	Katholieike Universiteit Leuven, Belgium	Self	de Cauwer, I.	F	Genotype-by-environment interaction and assessment of phenotypic stability of *Musa* germplasm in sub-Saharan Africa
MSc	Britain	Wye College, London	Self	Craven-Griffiths, A.	F	An investigation into yam (*Dioscorea* spp.) associated mycorrhiza and their application as intermediate technology for micropropagated yam in West Africa
MSc	Austria	U Agriculture, Vienna	Austrian	Czerwenka-W, I.	F	Mechanism of resistance to *Striga hermonthica* in maize
Plant Health Management						
PhD	Nigeria	U Ibadan, Nigeria	IITA	Ojo, B.	M	Interactions between exotic and local phytoseiids and their prey in the cassava agroecosystem in Ajibode
PhD	Kenya	U Nairobi, Kenya	IITA	Safary, A.	M	Isolation and germination of stimulants of *Striga hermonthica* (Del.) Benth. from non-host plant parts and field tests of plant efficacy in germination stimulation
PhD	Burkina Faso	U Paris, France	DFPV	Ouedraogo, A.	M	Biological control of locusts and grasshoppers with entomopathogic fungi
PhD	Germany	U Berlin, Germany	Self	Hell, K.	F	*Aspergillus* spp. and resulting aflatoxins in maize
PhD	Kenya	Louisiana State U, USA	RF	Rugutt, J. K.	M	Control of witchweed (*Striga*) by natural products from native plants
MSc	Nigeria	U Benin, Nigeria	Self	Ruffai, A. A.	M	Biological studies on the anthracnose disease of yam (*Dioscorea species*) caused by *Colletotrichum gloeosporioides*
MSc	Nigeria	Old Dominion U, Virginia, USA	ODU	Ndirpaya, D. Y.	M	Partial host-range of *Striga aspera* (Willd.) Bent (*Euphrasia aspera* Willd.) as determined by stimulation of seed germination and extent of parasitism
MSc	Togo	U Benin, Togo	Self	D'Almeida, A.	M	Biological control of whiteflies
MSc	Netherlands	Wageningen Agricultural U, Netherlands	Self	Bar, J.	M	Development of indexing techniques for viruses affecting water (*Dioscorea alata* L.) and white (*Dioscorea rotundata* Poir.) yam
MSc	Germany	U Gottingen, Germany	Self	Kuklinski, F.	M	Laboratory studies on control of African stem borers with *Beauveria bassiana*
MSc	Nigeria	Federal U of Technology, Akure, Nigeria	GTZ	Ogunkoya, M.	F	Comparative study of compartmentalized wooden silo and warehouse for grain storage in Ondo State
Resource and Crop Management						
PhD	Germany	U Gottingen, Germany	GTZ	Wick, B.	F	Enzyme activity on Alfisols
PhD	Somalia	U Gottingen, Germany	GTZ	Hassan, M. S.	M	Microbiological assessment of different tropical soils affected by decrease of soil fertility
PhD	Nigeria	U Ibadan, Nigeria	Self	Fagbola, O.	M	Decomposition rates of various leguminous woody foliages and their mixtures on late establishment of cassava (*Manihot esculenta* Crantz) as influenced by vesicular-arbuscular mycorrhizas in alley farming
PhD	Nigeria	U Reading, England	IITA	Anoka, U.	F	The effect of burning on the phenology of speargrass (*Imperata cylindica* [L.] Raeuschel) and the implications of pre-plant management on its persistence in arable fields
PhD	USA	Texas A&M U, USA	Self	Caldwell, J.	M	Competition for moisture and radiation in alley cropping systems
MSc	Nigeria	U Ibadan, Nigeria	Self	Gungula, D. T.	M	Nutrient balance in maize/soybean intercrop
MSc	Nigeria	U Ibadan, Nigeria	IITA	Akhalumhe, O. Y.	M	Economics of marketing and postharvest losses of plantain in southern Nigeria
MSc	Nigeria	U Ibadan, Nigeria	GTZ	Ofodile, M.	F	Termite activity survey in the cropped field and forest of a selected humid zone
MSc	Nigeria	U Ibadan, Nigeria	Self	Adejuyigbe, C. O.	M	Soil microarthropods and litter decomposition under different cropping systems and fallow management in the humid tropics

Publications by IITA staff

Contributions by IITA staff to scientific literature that became available during 1994, including journal articles, papers in monographs or conference proceedings, research notes or disease reports, and edited monographs. Also included are (1) publications based on work done by IITA staff prior to their joining IITA, especially where the work reported is of interest to IITA; and (2) publications by staff who have left IITA, which are based on work done while they were at the Institute.

Adeniran, O.R., T.A. Adigun, M.I. Okoh, and O.T. Eyitayo. 1994.
Availability and use of CD-ROM products in Nigerian libraries and information centers. Electronic Library 12(3): 155–168.

Agueguia, A., C.A. Fatokun, and S.K. Hahn. 1994.
The genetics of resistance to cocoyam root rot blight complex disease in *Xanthosoma sagittifolium* (L.) Schott. Pages 438–442 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Akem, C.N., and R. Asiedu. 1994.
Distribution and severity of yam anthracnose in Nigeria. Pages 297–301 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Akem, C.N., and K.E. Dashiell. 1994.
Effect of planting date on severity of frogeye leaf spot and grain yield of soybeans. Crop Protection 13 (8): 607–610.

Akinlosotu, T.A., L.E.N. Jackai, N.N. Ntonifor, A.T. Hassan, C.W. Agyakwa, J.A. Odebiyi, A.E. Akingbohungbe, and H.W. Rossel. 1993.
Spiralling whitefly, *Aleurodicus dispersus*, in Nigeria. FAO Plant Protection Bulletin 41/2: 127–129.

Alvarez, M.N. 1994.
An integrated network approach in root crops research. Pages 400–405 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Asanzi, C.M., N.A. Bosque-Pérez, I.W. Buddenhagen, D.T. Gordon, and L.R. Nault. 1994.
Interactions among maize streak virus disease, leafhopper vector populations and maize cultivars in forest and savanna zones of Nigeria. Plant Pathology 43: 145–157.

Berner, D.K., A.E. Awad, and E.I. Aigbokhan. 1994.
Potential of imazaquin seed treatment for control of *Striga gesnerioides* and *Alectra vogelii* in cowpea (*Vigna unguiculata*). Plant Disease 78(1): 18–23.

Berner, D.K., K.F. Cardwell, B.O. Faturoti, F.O. Ikie, and O.A. Williams. 1994.
Relative roles of wind, crop seeds, and cattle in dispersal of *Striga* spp. Plant Disease 78(4): 402–406.

Bokanga, M. 1994.
Distribution of cyanogenic potential in the cassava germplasm. Pages 117–123 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Bokanga, M. 1994.
Processing of cassava leaves for human consumption. Pages 203–207 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Bokanga, M. 1994.
The cyanogenic potential of cassava. Pages 336–339 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Bokanga, M., and E. Otoo. 1994.
Cassava-based foods: How safe are they? Pages 225–232 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Bokanga, M., I.J. Ekanayake, A.G.O. Dixon, and M.C.M. Porto. 1994.
Genotype-environment interactions for cyanogenic potential in cassava. Pages 131–139 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Borgemeister, C., C. Adda, B. Djomamou, P. Degbey, A. Agbaka, F. Djossou, W.G. Meikle, and R.H. Markham. 1994.
The effect of maize cob selection and the impact of field infestation on stored maize losses by the larger grain borer (*Prostephanus truncatus* (Horn) Col., Bostrichidae) and associated storage pests. Pages 906–909 *in* Stored product protection, Vol. 2, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ., 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Cardwell, K.F., and L. Dongo. 1994.
Effect of extracts from nine plant species found in Africa on the mycelial growth of *Aspergillus flavus* Link. Pages 978–980 *in* Stored product protection, Vol. 2, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ, 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Carsky, R.J., L. Singh, and R. Ndikawa. 1994.
Effect of herbicide and handweeding on current and subsequent season *Striga hermonthica* density on sorghum. International Journal of Pest Management 40(2): 111–116.

Chakupurakal, J., R.H. Markham, P. Neuenschwander, M. Sakala, C. Malambo, D. Mulwanda, E. Banda, A. Chalabesa, T. Bird, and T. Haug. 1994.
Biological control of the cassava mealybug, *Phenacoccus manihoti* (Homoptera: Pseudococcidae), in Zambia. Biological Control 4(3): 254–262.

Dahniya, M.T., M.O. Akoroda, M.N. Alvarez, P.M. Kaindaneh, J. Ambe-Tumanteh, J.E. Okeke, and A. Jalloh. 1994.
Development and dissemination of appropriate root crops packages to farmers in Africa. Pages 2–9 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Dahniya, M.T., A. Jalloh, and H.C. Ezumah. 1994.
Intercrop yields of cassava and rice as influenced by cassava variety and population. Pages 194–199 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 October 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

de Carvalho, F., W. Boerjan, I. Ingelbrecht, A. Depicker, D. Inze, and M. Van Montagu. 1994.
Post-transcriptional gene silencing in transgenic plants. Pages 437–452 *in* Plant molecular biology, edited by G. Coruzzi and P. Puigdomènech. NATO ASI Series, vol H 81. Springer-Verlag, Berlin, Germany.

Defloor, I., R. Leijskens, M. Bokanga, and J.A. Delcour. 1994.
Impact of genotype and crop age on the breadmaking and physico-chemical properties of flour produced from cassava (*Manihot esculenta* Crantz) planted in the dry season. Journal of the Science of Food and Agriculture 66(2): 193–202.

Dixon, A.G.O., R. Asiedu, and M. Bokanga. 1994.
Breeding of cassava for low cyanogenic potential: problems, progress and prospects. Pages 153–161 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Dixon, A.G.O., R. Asiedu, and S.K. Hahn. 1994.
Genotypic stability and adaptability: analytical methods and implications for cassava breeding for low-input agriculture. Pages 130–137 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Dreyer, H., J. Baumgärtner, and M. Tamò. 1994.
Seed damaging field pests of cowpea (*Vigna unguiculata*) L. Walp.) in Benin: occurrence and pest status. International Journal of Pest Management 40(3): 252–260.

Eggleston, G., and R. Asiedu. 1994.
Effects of boiling on the texture of cassava clones: a comparison of compressive strength, intercellular adhesion and physico-chemical composition of the tuberous roots. Tropical Science 34(3): 259–273.

Eggleston, G., and P. Omoaka. 1994.
Alternative breads from cassava flour. Pages 243–248 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Ekanayake, I.J. 1994.
Deleterious influence of water-logging on potato in warm climates. Pages 506–510 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Ekanayake, I.J., A.G.O. Dixon, R. Asiedu, and A-M.N. Izac. 1994.
Improved cassava for inland valley agro-ecoystems. Pages 204–208 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Ekanayake, I.J., R. Ortiz, and D.R. Vuylsteke. 1994.
Influence of leaf age, soil moisture, VPD and time of day on leaf conductance of various *Musa* genotypes in a humid forest–moist savanna transition site. Annals of Botany 74: 173–178.

Everett, L.A., J.T. Eta-Ndu, M. Ndioro, and I. Tabi. 1994.
Application of a modified comprehensive breeding system for maize (*Zea mays* L.) in Cameroon. Maydica 39: 231–237.

Everett, L.A., J.T. Eta-Ndu, M. Ndioro, I. Tabi, and S.K. Kim. 1994.
Registration of 18 first-cycle tropical midaltitude maize germplasm lines. Crop Science 34: 1422.

Everett, L.A., J.T. Eta-Ndu, M. Ndioro, I. Tabi, and S.K. Kim. 1994.
Registration of 19 second-cycle tropical midaltitude maize germplasm lines. Crop Science 34: 1419–1420.

Everett, L.A., J.T. Eta-Ndu, M. Ndioro, and I. Tabi. 1994. Registration of four tropical midaltitude maize germplasm populations. Crop Science 34: 1420–1421.

Ezomo, E.O. 1994.
Information management and the new technology: an appreciation of the CD-ROM. Library Forum 13(2–3): 3–6.

Franzen, H., R. Lal, and W. Ehlers. 1994.
Tillage and mulching effects on physical properties of a tropical Alfisol. Soil and Tillage Research 28(3–4): 329–346.

Gauhl, F. 1993.
Some aspects of black sigatoka epidemiology in Central America and outlook for future research in sub-Saharan Africa. Pages 276–289 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Gauhl, F. 1994.
Epidemiology and ecology of black sigatoka (*Mycosphaerella fijiensis* Morelet) on plantain and banana (*Musa* spp.) in Costa Rica, Central America. International Network for the Improvement of Banana and Plantain, Montpellier, France. 120 pp.

Gauhl, F., K.N. Mobambo, C. Pasberg-Gauhl, R. Swennen, and D. Vuylsteke. 1994.
Preliminary evaluation of black sigatoka resistance in IITA plantain hybrids. Pages 567–574 *in* Proceedings, 10th Reunion Meeting, Association for Cooperation in Banana Research in the Caribbean and Tropical America (ACORBAT), 3–8 Nov 1991, Tabasco, Mexico, Corporación Bananera Nacional, Costa Rica.

Gichuru, M.P. 1994.
Regeneration of a degraded ultisol with *Tephrosia candida* in the humid zone of southeastern Nigeria. Interciencia 19(6): 382–386.

Goergen, G., and P. Neuenschwander. 1994.
Chartocerus hyalipennis (Hayat) (Hym: Signiphoridae), a gregarious hyperparasitoid on mealybugs (Hom.: Pseudococcidae): biology and host range in West Africa. Bulletin de la société entomologique suisse 67: 297–308.

Gold, C.S., M.W. Ogenga-Latigo, W. Tushemereirwe, I. Kashaija, and C. Nankinga. 1993.
Farmer perceptions of banana pest constraints in Uganda: Results from a rapid rural appraisal. Pages 3–24 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Gold, C.S. 1994.
Ecology of cassava white flies in Colombia. Pages 307–310 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Gold, C.S., P.R. Speijer, N.D. Rukazambuga, and E.B. Maramura. 1994.
Assessment of banana weevils in East African highland banana systems and strategies for control. Pages 170–190 *in* Banana nematodes and weevil borers in Asia and the Pacific, edited by R.V. Valmayor, R.G. Davide, J.M. Stanton, N.L. Treverrow, and V.N. Roa. Proceedings of a workshop held at Serdang, Selangor, Malaysia, 18–22 Apr 1994. INIBAP, Montpellier, France.

Green, K.R., and S.A. Simons. 1994.
"Dead skin" on yams (*Dioscorea alata*) caused by *Colletotrichum gloeosporioides*. Plant Pathology 43: 1062–1065.

Gyansa-Ameyaw, C.E., S.K. Hahn, N.M. Alvarez, and E.V. Doku. 1994.
Determination of optimum sett size for white guinea yam (*Dioscorea rotundata* Poir.) seed yam production: trends in sprouting in the presprout nursery and field performance. Pages 335–341 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Hahn, S.K. 1994.
Root crops for food security in sub-Saharan Africa. Pages 16–21 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Hauser, S., and M.P. Gichuru. 1994.
Root distribution of *Dactyladenia (Acioa) barteri* and *Senna (Cassia) siamea* in alley cropping on Ultisol. II. Impact on water regime and consequences for experimental design. Agroforestry Systems 26: 9–21.

Herren, H.R., and M. Tamò. 1994.
Ecologically sustainable and environmentally sound approach to plant protection in land management. Pages 97–111 *in* Proceedings, International Workshop on Sustainable Land Management for the 21st Century, edited by R.C. Wood and J. Dumanski, 20–26 Jun 1993, University of Lethbridge, Lethbridge, Canada. Available from the University of Lethbridge.

Hulugalle, N.R. 1994.
Long-term effects of land clearing methods, tillage systems and cropping systems on surface soil properties of a tropical Alfisol in S.W. Nigeria. Soil Use and Management 16: 25–30.

Hulugalle, N.R., and J.N. Ndi. 1994.
Changes in soil properties of a newly-cleared Ultisol due to establishment of hedgerow species in alley cropping systems. Journal of Agricultural Science, Cambridge 122: 435–443.

Hulugalle, N.R., H.C. Ezumah, and T. Leyman. 1994.
Changes in surface soil properties of a no-tilled tropical Alfisol due to intercropping maize, cassava and 'egusi' melon. Field Crops Research 36: 191–200.

Ikotun, T., and S.K. Hahn. 1994.
Screening cassava cultivars for resistance to the cassava anthracnose disease (CAD). Pages 178–183 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Ingelbrecht, I., H. Van Houdt, M. Van Montagu, and A. Depicker. 1994.
Posttranscriptional silencing of reporter transgenes in tobacco correlates with DNA methylation. Proceedings of the National Academy of Science, USA 91: 10502–10506.

Izac, A-M.N., M.J. Swift, and K. Dvorak. 1994.
Integration of economics and ecology in addressing sustainability issues in agroecosystems. Pages 53–58 *in* Social science in the CGIAR; proceedings of a meeting of CGIAR scientists held at the International Service for National Agricultural Research (ISNAR), edited by M.P. Collinson and K.W. Platais. The Hague, the Netherlands, Aug 1992. World Bank, Washington, DC, USA.

Jagtap, S.S. 1993.
Diagnostic survey site selection using GIS for effective biological and integrated control of highland banana pests. Pages 25–36 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Jalloh, A., M.T. Dahniya, and H.C. Ezumah. 1994.
Productivity of cassava-rice intercrop as influenced by cassava variety and time of introducing rice into cassava. Pages 200–204 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Jarret, R.L., K.V. Bhat, P. Cregan, R. Ortiz, and D. Vuylsteke. 1994.
Isolation of microsatellite DNA markers in *Musa*. InfoMusa 3(2): 3–4.

Jeon, Y.W., and L.S. Halos. 1994.
Technical performance of a root crop chipping machine. Pages 94–100 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Kadiata, B.T., and K. Mulongoy. 1994.
Effect of pruning frequency on nitrogen accumulation and fixation in two woody legumes. Pages 203–213 *in* Recent developments in biological nitrogen fixation research in Africa. Proceedings, V International Conference of the African Association for Biological Nitrogen Fixation (AABNF), edited by M. Sadiki and A. Hilali, 14–19 Sep 1992 Rabat, Morocco. Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco.

Kang, B.T., F.K. Akinnifesi, and J.L. Pleysier. 1994.
Effect of agroforestry woody species on earthworm activity and physicochemical properties of worm casts. Biology and Fertility of Soils 18(3): 193–199.

Kang, B.T., F.K. Akinnifesi, and D.O. Ladipo. 1994.
Performance of selected woody agroforestry species grown on an Alfisol and an Ultisol in the humid lowland of West Africa, and their effects on soil properties. Journal of Tropical Forest Science 7(2): 303–312.

Kashaija, I.N., P.R. Speijer, C.S. Gold, and S.R. Gowen. 1994.
Occurrence distribution and abundance of plant parasitic nematodes of bananas in Uganda. African Crop Science Journal 2: 99–104.

Kim, S.K. 1994.
Breeding for *Striga hermonthica* tolerant open-pollinated maize varieties in Africa. Pages 263–273 *in* Progress in food grain research and production in semi-arid Africa, edited by J.M. Menyonga, T. Bezneh, J.Y. Yayock, and I. Soumana. Proceedings, SAFGRAD Inter-Network Conference, Niamey, Niger, 7–14 Mar 1991. OAU/STRC/SAFGRAD, Ouagadougou, Burkina Faso.

Kim, S.K. 1994.
Genetics of maize tolerance of *Striga hermonthica*. Crop Science 34(4): 900–907.

Kim, S.K., A.Y. Akintunde, and P. Walker. 1994.
Responses of maize, sorghum and millet host plants to infestation by *Striga hermonthica*. Crop Protection 13(8): 582–590.

Koudokpon, V., J. Brouwers, M.N. Versteeg, and A. Budelman. 1994.
Priority setting in research for sustainable land use: the case of the Adja Plateau, Benin. Agroforestry Systems 26: 101–122.

Lane, J.A., T.H.M. Moore, D.V. Child, K.F. Cardwell, B.B. Singh, and J.A. Bailey. 1994.
Virulence characteristics of a new race of the parasitic angiosperm, *Striga gesnerioides*, from southern Benin on cowpea (*Vigna unguiculata*). Euphytica 72(3): 183–188.

Lema, K.M., D.S.O. Osiru, and S.K. Hahn. 1994.
Effectiveness of the polyethylene plastic mulch as a control measure against sweet potato weevils (*Cylas* spp., Coleoptera: Curculionidae). Pages 302–306 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Mahungu, N.M., H.R. Chheda, M.E. Aken'Ova, and S.K. Hahn. 1994.
Correlated response and use of selection index in cassava. Pages 114–117 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Mahungu, N.M., S.K. Hahn, and H.R. Chheda. 1994.
Cyanide and cassava breeding. Pages 101–105 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Markham, R.H., F. Djossou, J.M. Hirabayashi, P. Novillo, V.F. Wright, R.M. Rios, F.J. Trujillo, W.G. Meikle, and C. Borgemeister. 1994.
Biological control in the context of an integrated management strategy for the larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and associated storage pests. Pages 1106–1111 *in* Stored product protection, Vol. 2, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ, 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Markham, R.H., C. Borgemeister, and W.G. Meikle. 1994.
Can biological control resolve the larger grain borer crisis? Pages 1087–1097 *in* Stored product protection, Vol. 2, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ, 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Maroya, G.N., and A.G.O. Dixon. 1994.
Utilisation des paramètres de stabilité dans la sélection des clones de manioc pour le rendement en racine. Pages 111–115 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Mbahe, R.E., M.E. Aken'Ova, and S.K. Hahn. 1994.
Germination of cassava (*Manihot esculenta* Crantz) pollen. Pages 172–177 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Mobambo, K.N., K. Zuofa, F. Gauhl, M.O. Adeniji, and C. Pasberg-Gauhl. 1994.
Effect of soil fertility on host response to black leaf streak of plantain (*Musa* spp., AAB group) under traditional farming systems in southwestern Nigeria. International Journal of Pest Management 40(1): 75–80.

Mohamoud, Y.M. 1994.
Effect of mound height and cassava cultivar on cassava performance under a fluctuating water table. Agricultural Water Management 26(3): 201–212.

Muaka Toko, R.J. O'Neil, and J.S. Yaninek. 1994.
The effect of cassava exudate on development, reproduction and survival of *Typhlodromalus limonicus* (Garman & McGregor) during low prey conditions. Experimental and Applied Acarology 18: 221–231.

Neuenschwander, P., and M. Zweigert. 1994.
Biological control of cassava mealybug and green spider mite in eastern and southern Africa. Pages 13–28 *in* Root and tuber crops pest management in east and southern Africa. Proceedings of a workshop held in Mombasa, Kenya, 10–14 Aug 1992, edited by G. B. Allard, L.G. Skoglund, P. Neuenschwander, and R.J. Murphy. IIBC/CABI, Nairobi, Kenya.

Neuenschwander, P.C. Boavida, A. Bokonon-Ganta, A. Gado, and H.R. Herren. 1994.
Establishment and spread of *Gyranusoidea tebygi* Noyes and *Anagyrus mangicola* Noyes (Hymenoptera: Encyrtidae), two biological control agents released against the mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) in Africa. Biocontrol Science and Technology 4: 61–69.

Ng, N.Q., and S.Y.C. Ng. 1994.
Approaches for yam germplasm conservation. Pages 135–140 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Ng, S.Y.C. 1994.
Production and distribution of virus-free yam (*Dioscorea rotundata* Poir.). Pages 324–328 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Ng, S.Y.C., M.A. Ngu, and T.A.O. Ladeinde. 1994.
Embryo culture of yams: germination and callus induction. Pages 141–144 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Njock, T.E., G.I. Atiri, G. Thottappilly, and S.K. Hahn. 1994.
Distribution and disease recovery of African cassava mosaic virus (ACMV) in stems of resistant and susceptible cassava. Pages 149–152 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Nweke, F.I. 1994.
Cassava distribution in sub-Saharan Africa. COSCA Working Paper No. 12. Collaborative Study of Cassava in Africa (COSCA). IITA, Ibadan, Nigeria. 38 pp.

Nweke, F.I. 1994.
Cassava processing in sub-Saharan Africa: the implications for expanding cassava production. Outlook on Agriculture 23(3): 197–205.

Nweke, F.I. 1994.
Processing potential for cassava production growth in Africa. COSCA Working Paper No. 11. Collaborative Study of Cassava in Africa (COSCA). IITA, Ibadan, Nigeria. 47 pp.

Nweke, F.I., and M. Bokanga. 1994.
Importance of cassava processing for production in sub-Saharan Africa. Pages 401–412 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Nweke, F.I., A.G.O. Dixon, R. Asiedu, and S.A. Folayan. 1994.
Attributes of cassava varieties desired by farmers in sub-Saharan Africa. Pages 65–92 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Nweke, F.I., R. Polson, and J. Strauss. 1994.
Cassava production trends in Africa. Pages 311–321 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S,K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Nweke, F.I., A.G.O. Dixon, R. Asiedu, and S.A. Folayan. 1994.
Cassava varietal needs of farmers and the potential for production growth in

Africa. COSCA Working Paper No. 10. Collaborative Study of Cassava in Africa (COSCA). IITA, Ibadan, Nigeria. 239 pp.

Nweke, F.I., S.K. Hahn, and B.O. Ugwu. 1994.
Circumstances of rapid spread of cultivation of improved cassava varieties in Nigeria. Journal of Farming Systems Research–Extension 4(3): 93–119.

Nweke, F.I., E.C. Okorji, J.E. Njoku, and D.J. King. 1994.
Expenditure elasticities of demand for major food items in southeast Nigeria. Tropical Agriculture 71(3): 229–234.

Okogun, J.A., K. Mulongoy, C.T.I. Odu, and A.A. Agboola. 1994.
Screening of multipurpose trees for alley cropping on Alfisol and Ultisol. Pages 551–562 *in* Recent developments in biological nitrogen fixation research in Africa. Proceedings, V International Conference of the African Association for Biological Nitrogen Fixation (AABNF), edited by M. Sadiki and A. Hilali, 14–19 Sep 1992,Rabat, Morocco. Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco.

Omoaka, P.E., and M. Bokanga. 1994.
Cassava in the production of bread and bakery products. Pages 340–342 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Orkwor, G.C., O.U. Okereke, F.O.C. Ezedinma, S.K. Hahn, H.C. Ezumah, and I.O. Akobundu. 1994.
The response of yam (*Dioscorea rotundata* Poir.) to various periods of weed interference in an intercropping with maize (*Zea mays* L.), okra (*Abelmoschus esculentus* L. Moench), and sweet potato (*Ipomoea batatas* L. Lam). Pages 349–354 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Ortiz, R., and Z. Huaman. 1994.
Morphology and tuber characteristics. Pages 263–283 *in* Potato genetics, edited by J.E. Bradshaw and G.R. Mackay. CAB International, Wallingford, Oxon, UK.

Ortiz, R., and J. Izquierdo. 1994.
Yield stability of hybrid and open pollinated tomato cultivars in Latin America and the Caribbean. HortScience 29: 1175–1177.

Ortiz, R., and S.J. Peloquin. 1994.
Effect of sporophytic heterozygosity on the male gametophyte of the tetraploid potato (*Solanum tuberosum*). Annals of Botany 73: 61–64.

Ortiz, R., and S.J. Peloquin. 1994.
Use of 24 chromosome potatoes (diploids and dihaploids) for genetic analysis. Pages 133–153 *in* Potato genetics, edited by J.E. Bradshaw and G.R. Mackay. CAB International, Wallingford, Oxon, UK.

Ortiz, R., and D. Vuylsteke. 1994.
Future strategy for *Musa* improvement. Pages 40–42 *in* Banana and plantain breeding: priorities and strategies, Proceedings of the First Meeting of the *Musa* Breeders' Network, La Lima, Honduras, 2–3 May 1994. International Network for the Improvement of Banana and Plantain, Montpellier, France.

Ortiz, R., and D.R. Vuylsteke. 1994.
Genetics of apical dominance in plantain (*Musa* spp., AAB group) and improvement of suckering behavior. Journal of the American Society for Horticultural Science 119(5): 1050–1053.

Ortiz, R., and D.R. Vuylsteke. 1994.
Inheritance of albinism in banana and plantain (*Musa* spp.) and its significance in breeding. HortScience 29(8): 903–905.

Ortiz, R., and D. Vuylsteke. 1994.
Inheritance of black sigatoka disease resistance in plantain-banana (*Musa* spp.) hybrids. Theoretical and Applied Genetics 89: 146–152.

Ortiz, and D. Vuylsteke. 1994.
Plantain breeding at IITA. Pages 130–156 *in* The improvement and testing of *Musa*: a global partnership, edited by D.R. Jones. Prodeedings of the First Global Conference of the International *Musa* Testing program held at FHIA, Honduras 27–30 Apr 1994. INIBAP, Montpellier, France.

Ortiz, R., and D. Vuylsteke. 1994. P
lot technique studies on yield trials of plantain propagated by in vitro methods. Infomusa 3(1): 20–21.

Ortiz, R., and D. Vuylsteke. 1994.
Trisomic segregation ratios and genome differentiation in AAB plantain. Infomusa 3(1): 21.

Ortiz, R., M. Iwanaga, and S.J. Peloquin. 1994.
Breeding potatoes for developing countries using wild tuber bearing *Solanum* spp. and ploidy manipulations. Journal of Genetics and Breeding 48: 89–98.

Osho, S.M. 1994.
Methods for the dissemination of food processing technologies: the soybean example in Nigeria. Pages 385–391 *in* Cassava safety, edited by M. Bokanga, A.J.A. Essers, N. Poulter, H. Rosling, and O. Tewe. Proceedings of the International Workshop on Cassava Safety, Ibadan, Nigeria, 1–4 Mar 1994. Acta Horticulturae No. 375. International Society of Horticultural Science, Wageningen, the Netherlands.

Osiname, O., and J. Tonye. 1994.
Alley farming research at the International Institute of Tropical Agriculture—IITA. Entwicklung + Ländlicher Raum 5: 31–32.

Osiru, D.S.O., and S.K. Hahn. 1994.
Effects of mulching materials on the growth, development, and yield of white yam. African Crop Science Journal 2(2): 153–160.

Otoo, J.A., A.G.O. Dixon, R. Asiedu, F.E. Okeke, G.N. Maroya,, K. Tougnon, O.O. Okoli, J.P. Tetteh, and S.K. Hahn. 1994.
Genotype ¥ environment interaction studies with cassava. Pages 146–148 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Pasberg-Gauhl, C. 1993.
Symptom development of black sigatoka leaf spot on young or adult banana and plantain plants after natural inoculation. Pages 263–275 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Pasberg-Gauhl, C., F. Gauhl, and D. Vuylsteke. 1994.
Sigatoka research at the International Institute of Tropical Agriculture, Nigeria. Pages 607–615 *in* Proceedings, 10th Reunion Meeting, Association for Cooperation in Banana Research in the Caribbean and Tropical America (ACORBAT), 3–8 Nov 1991, Tabasco, Mexico. Corporación Bananera Nacional, Costa Rica.

Porto, M.C.M., R. Asiedu, A.G.O. Dixon, and S.K. Hahn. 1994.
An agroecologically-oriented introduction of cassava germplasm from Latin America into Africa. Pages 118–129 *in* Tropical root crops in a developing economy. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, edited by F. Ofori and S.K. Hahn, 20–26 Oct 1991, Accra, Ghana. ISTRC/Government of Ghana/IITA copublication.

Reese, J.C., D.C. Margolies, E.A. Backus, S. Noyes, P. Bramel-Cox, and A.G.O. Dixon. 1994.
Characterization of aphid host plant resistance and feeding behavior through use of a computerized insect feeding monitor. Pages 52–72 *in* History, development, and application of AC electronic insect feeding monitors, edited by M.M. Ellsbury, E.A. Backus, and D.L. Ullman. Entomological Society of America, Lanham, Maryland, USA.

Rossel, H.W., C.M. Changa, and G.I. Atiri. 1994.
Quantification of resistance to African cassava mosaic virus (ACMV) in IITA-improved, mosaic-resistant cassava breeding materials. Pages 280–287 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Ruhigwa, B.A., M.P. Gichuru, D.S.C. Spencer, and R. Swennen. 1994.
Economic analysis of cut-and-carry, and alley cropping systems of mulch production for plantains in south-eastern Nigeria. Agroforestry Systems 26: 131–138.

Sanginga, N., S.K.A. Danso, F. Zapata, and G.D. Bowen. 1994.
Field validation of intraspecific variation in phosphorus use efficiency and nitrogen fixation by provenances of *Gliricidia sepium* grown in low P soils. Applied Soil Ecology 1: 127–138.

Sanginga, N., S.K.A. Danso, K. Mulongoy, and A.A. Ojeifo. 1994.
Persistence and recovery of introduced *Rhizobium* ten years after inoculation on *Leucaena leucocephala* grown on an Alfisol in southwestern Nigeria. Plant and Soil 159: 199–204.

Schilder, A.M.C., and G.C. Bergstrom. 1994.
Infection of wheat seed by *Pyrenophora tritici-repentis*. Canadian Journal of Botany 72: 510–519.

Schilder, A.M.C., and G.C. Bergstrom. 1994.
Pyrenophora tritici-repentis as a component of the fungal flora of winter wheat seed in New York. Seed Science and Technology 22: 285–297.

Shah, P.A., I. Godonou, C. Gbongboui, and C.J. Lomer. 1994.
Natural levels of fungal infections in grasshoppers in northern Benin. Biocontrol Science and Technology 4: 331–342.

Shannon, D.A., and M. Mwamba Kalala. 1994.
Adoption of soybean in sub-Saharan Africa: a comparative analysis of production and utilization in Zaire and Nigeria. Agricultural Systems 46(4): 369–384.

Shannon, D.A., W.O. Vogel, and K.N. Kabaluapa. 1994.
The effects of alley cropping and fertilizer application on continuously cropped maize. Tropical Agriculture 71(3): 163–169.

Shanower, T.G., F. Schulthess, and N. Bosque-Pérez. 1993.
The effect of larval diet on the growth and development of *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) and *Eldana saccharina* Walker (Lepidoptera: Pyralidae). Insect Science and its Application 14(5–6): 681–685.

Simons, S.A., and K.R. Green. 1994. Quantitative methods for assessing the severity of anthracnose on yam (*Dioscorea alata*). Tropical Science 34: 216–224.

Simwambana, M.S.C., T.U. Ferguson, D.S.O. Osiru, and S.K. Hahn. 1994. Effect of time to first shoot removal and the amount of shoots removed on the yield and quality of cassava leaves and tubers. Tropical Agriculture 71(1): 41–48.

Smith, J. 1994. New challenge confronting social scientists in IARCs with ecoregional mandates. Pages 11–13 *in* Social science in the CGIAR: proceedings of a meeting of CGIAR scientists held at the International Service for National Agricultural Research (ISNAR), edited by M.P. Collinson and K.W. Platais, Aug 1992, the Hague, the Netherlands. World Bank, Washington, DC, USA.

Smith, J., and G.K. Weber. 1994. Strategic research in heterogenous mandate areas: An example from the West African savanna. Pages 545–565 *in* Agricultural technology: Policy issues for the international community, edited by J.R. Anderson. CAB International (in association with the World Bank), Wallingford, Oxon, UK.

Smith, J., A.D. Barau, A. Goldman, and J.H. Mareck. 1994. The role of technology in agricultural intensification: the evolution of maize production in the northern Guinea savanna of Nigeria. Economic Development and Cultural Change 42(3): 537–554.

Speijer, P.R., and R.A. Sikora. 1993. Influence of a complex disease involving *Pratylenchus goodeyi* and a nonpathogenic strain of *Fusarium oxysporum* on banana root health. Pages 231–239 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Speijer, P.R., C.S. Gold, I.N. Kashaija, and E.B. Karamura. 1994. Assessment of nematode damage in East African highland banana systems. Banana nematodes and weevil borers in Asia and the Pacific, edited by R.V. and V.N. Roa. Proceedings of a workshop held at Serdang, Selangor, Malaysia, 18–22 Apr 1994. INIBAP, Montpellier, France.

Théberge, R.L. (original ed.), K. Wydra, and J.S. Yaninek (revision eds.). 1994. Common African pests and diseases of cassava, yam, sweet potato and cocoyam. Beta version, available on CD-ROM. International Institute of Tropical Agriculture and University of Florida, FAIRS CD-ROM Unit, Gainesville, Florida, USA.

Thenkabail, P.S., A.D. Ward, and J.G. Lyon. 1994. Impacts of agricultural management practices on soybean and corn crops evident in ground-truth data and thematic mapper vegetation indices. Transactions of the ASEA 37(3): 989–995.

Thenkabail, P.S., A.D. Ward, and J.G. Lyon. 1994. Landsat-5 thematic mapper models of soybean and corn crop characteristics. International Journal of Remote Sensing 15(1): 49–61.

Thenkabail, P.S., A.D. Ward, J.G. Lyon, and C.J. Merry. 1994. Thematic mapper vegetation indices for determining soybean and corn growth parameters. Photogrammetric Engineering and Remote Sensing 60(4): 437–442.

Thielen, R., van O. Ajuonu, V. Schade, P. Neuenschwander, A. Adité, and C. Lomer. 1994. Importation, releases, and establishment of *Neochetina* spp. (Col., Curculionidae) for the biological control of water hyacinth, *Eichhornia crassipes* (Lil., Pontederiaceae), in Benin, West Africa. Entomophaga 39: 179–188.

Thottappilly, G., N.Q. Ng, and H.W. Rossel. 1994. Screening germplasm of *Vigna vexillata* for resistance to cowpea mottle virus. International Journal of Tropical Plant Diseases 12: 75–80.

Tian, G., and B.T. Kang. 1994. Evaluation of phytotoxic effects of *Gliricidia sepium* (Jacq.) Walp prunings on maize and cowpea seedlings. Agroforestry Systems 26: 249–254.

Tian, G. L. Brussaard, and B.T. Kang. 1995. An index for assessing the quality of plant residues and evaluating their effects on soil and crop in the (sub-) humid tropics. Applied Soil Ecology 2: 25–32.

Tonye, J., B. Duguma, and T. Tiki-Manga. 1994. Stepwise approach to alley cropping technology development and transfer in the forest zone of Cameroon. Agroforestry Systems 28: 269–278.

Traore, L., C,S. Gold, J.G. Pilon, and G. Boivin. 1994. Effects of temperature on embryonic development of banana weevil, *Cosmopolites sordidus*. African Crop Science Journal 2: 111–116.

Tushemereirwe, W.K., C.S. Gold, P.R. Speijer, and M. Holdemess. 1994. Foliar diseases of banana in Uganda: Results from a diagnostic survey. African Crop Science Journal 2: 145–150.

Udoh, J., T. Ikotun, and K.F. Cardwell. 1994. Storage systems for maize (*Zea mays* L.) in Nigeria from five agro-ecological zones. Pages 960–965 *in* Stored product protection, Vol. 2, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ, 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Vanlauwe, B., L. Dendooven, and R. Merckx. 1994. Residue fractionation and decomposition: The significance of the active fraction. Plant and Soil 158: 263–274.

Versteeg, M., J. Adanguidi, J. Djenotin, and R. Nonfon. 1994. Effective participatory research involving farmers, nongovernment organizations, national agricultural research systems, and international agricultural research systems, to improve food security in northern Bénin. Pages 274–275 *in* Proceedings, International Symposium on Systems-Oriented Research in Agriculture and Rural Development, 21–25 Nov 1994, Montpellier, France. CIRAD/SAR, Montpellier, France.

Versteeg, M., J. Adanguidi, J. Djenotin, and R. Nonfon. 1994. Recherche participative efficace entre paysans, ONG, SNRA et IITA pour controler *Striga hermonthica* au Nord du Bénin. Pages 413–433 *in* Proceedings, Regional Conference on Systèmes Agraires et Agriculture Durable en Afrique Sub-Saharienne, 7–11 Feb 1994, Cotonou, Benin. International Foundation for Science, Stockholm, Sweden.

Vowotor, K.A., N.A. Bosque-Pérez, and J.A. Ayertey. 1994. Effect of maize variety and storage form on oviposition and development of the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Pages 595–598 *in* Stored product protection, Vol. 1, Proceedings of the 6th International Working Conference on Stored-product Protection, edited by E. Highley, E.J. Wright, H.J. Banks, and B.R. Champ, 17–23 Apr 1994, Canberra, Australia. CAB International, Wallingford, Oxon, UK.

Vuylsteke, D., and R. Swennen. 1993. Development and performance of tetraploid hybrids of plantain (*Musa* spp., AAB group) with black sigatoka resistance. Pages 324–335 *in* Biological and integrated control of highland banana and plantain pests and diseases. Proceedings, Research Coordination Meeting, edited by C.S. Gold and B. Gemmill, 12–14 Nov 1991, Cotonou, Benin. IITA Benin Station, Cotonou, Benin.

Wanyera, N.M.W., S.K. Hahn, and M.E. Aken'Ova. 1994. Introgression of ceara rubber (*Manihot glaziovii* Muell-Arg) into cassava (*M. esculenta* Crantz): a morphological and electrophoretic evidence. Pages 125–130 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC—AB/CTA/IITA copublication.

Watanabe, K., M. Orillo, M. Iwanaga, R. Ortiz, R. Freyre, and S. Perez. 1994. Diploid potato germplasm derived from wild and landrace genetic resources. American Potato Journal 71: 599–617.

Wortmann, C.S., E.B. Karamura, and C.S. Gold. 1994. Nutrient flows from harvested pseudostems. African Crop Science Journal 2: 179–182.

Yaninek, J.S. 1994. Cassava plant protection in Africa. Pages 26–34 *in* Root crops for food security in Africa, edited by M.O. Akoroda. Proceedings of the Fifth Triennial Symposium of the International Society for Tropical Root Crops—Africa Branch, Kampala, Uganda, 22–28 Nov 1992. ISTRC-AB/CTA/IITA copublication.

Yaninek, J.S., and B. Kristensen. 1994. Phytophagous and predaceous mites commonly found in the cassava agroecosystem in Africa: A continent-wide geo-referenced database with more than 100,000 records from > 1,000 sites and 700 host plants. A FoxPro database on diskette available for either DOS or MacIntosh systems. International Institute of Tropical Agriculture, Cotonou, Benin.

Yaninek, J. S., P. Jones, H. Beck, and K. Wydra. 1994. Cassava information resources on CD-ROM: Directories of personnel, institutions and projects, indexed bibliographies, and five hyperlinked references concerning cassava in Africa. Including 140 digitized figures and photos. Beta version, available on CD-ROM. International Institute of Tropical Agriculture and University of Florida, FAIRS CD-ROM Unit, Gainesville, Florida, USA.

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Abbreviations used in the text

ABU Ahmadu Bello University (Nigeria)
AFNETA Alley Farming Network for Tropical Africa
AGCD *Administration générale de la coopération au développement* (Belgium)
AIDAB Australian International Development Bureau
ANU Australian National University
ASB Global Initiative on Alternatives to Slash and Burn
AUW Agricultural University, Wageningen
BADC/FDC Belgian Agency for Development Cooperation/Fund for Development Cooperation
BIONET BioNET—INTERNATIONAL Consultative Group— a Global Network for Biosystematics
BMZ *Bundesministerium für Zusammenarbeit* (Germany)
CABI Commonwealth Agricultural Bureau International (UK)
CGIAR Consultative Group on International Agricultural Research
CIAT *Centro Internacional de Agricultura Tropical*
CIDA Canadian International Development Agency
CIMMYT *Centro Internacional de Mejoramiento de Maiz y Trigo*
CIP *Centro Internacional de la Papa*
CIRAD *Centre de coopération internationale en recherche agronomique pour le développement* (France)
CP *Colegio de Postgraduados* (Mexico)
CRBP *Centre régionale bananiers et plantains*
CRI Crops Research Institute (Ghana)
CSIRO Commonwealth Scientific and Industrial Research Organization
CUSO Canadian Universities Service Overseas
DANIDA Danish International Development Agency
DFPV *Département de formation en protection des végétaux* (Benin)
DGIS *Directoraat Generaal voor Internationale Samenwerking* (Netherlands)
DRA *Direction de la recherche agronomique* (Benin, Central African Republic)
EAP *Escuela Agricola Panamericana* (Honduras)
EARNETT East African Root Crops Research Network
EEC European Economic Community
EMBRAPA *Empresa Brasiléira de Pesquisa Agropecuaria*
ESARC East and Southern Africa Regional Center
ESARRN East and Southern Africa Root Crops Research Network
ESCAPP Ecologically Sustainable Cassava Plant Protection (IITA)
ETH *Eidgenossisch Technische Hochschule* (Switzerland)
FAO Food and Agriculture Organization of the United Nations
FF Ford Foundation
FHIA *Fundacion Hondurena de Investigacion Agricola* (Honduras)
FRI Food Research Institute (Ghana)
GCF Gatsby Charitable Foundation
GGDP Ghana Grains Development Program
GIS geographic information system
GTZ *Gesellschaft für Technische Zusammenarbeit* (Germany)
IAEA International Atomic Energy Agency
IAR Institute for Agricultural Research, Samaru (Nigeria)
IAR&T Institute of Agricultural Research and Training (Nigeria)
IARCS international agricultural research center
ICIPE International Center of Insect Physiology and Ecology
ICRAF International Centre for Research in Agroforestry
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IDEFOR *Institut des forêts* (Côte d'Ivoire)
IDESSA *Institut des savanes* (Côte d'Ivoire)
IDRC International Development Research Centre
IER *Institut d'économie rurale* (Mali)
IFAD International Fund for Agricultural Development
IFPRI International Food Policy Research Institute
IIBC International Institute of Biological Control (UK)
IIE International Institute of Entomology (UK)
IIMI International Irrigation Management Institute
ILRI International Livestock Research Institute
INERA *Institut national d'études et de recherches agricoles* (Burkina Faso); *Institut national pour l'étude et la recherche agronomique* (Zaire)
INIA *Instituto Nacional Investigaçao Agronomica* (Mozambique)
INIBAP International Network for the Improvement of Bananas and Plantain (France)
INIFAP *Instituto Nacional de Investigaciones Forestales y Agropecuarias* (Mexico)
INRAN *Institut national de recherches agronomiques de Niger*
IPGRI International Plant Genetic Resources Institute
IRA *Institut de la recherche agronomique* (Cameroon)
IRAZ *Institut de recherche agronomique et zootechnique* (Burundi)
IRRI International Rice Research Institute
ISF Institute of Soil Fertility (Netherlands)
JIC John Innes Centre (UK)
JIRCAS Japan International Research Center for Agricultural Sciences
KUL *Katholieke Universiteit, Leuven* (Belgium)
LBSA/FAST *Laboratoire de biotechnologie et science des aliments, Faculté des sciences et techniques* (Côte d'Ivoire)
MARDI Malaysian Agricultural Research and Development Institute
NAERLS National Agricultural Extension and Research Liaison Service (Nigeria)
NAES Nyankpala Agricultural Experiment Station (Ghana)
NARO National Agricultural Research Organisation (Uganda)
NARS national agricultural research systems
NCRE National Cereals Research and Extension (Cameroon)
NCRI National Cereals Research Institute (Nigeria)
NGO non-governmental organization
NIFOR Nigerian Insitute of Oil Palm Research and Training
NIFTAL Nitrogen Fixation in Tropical Agricultural Legumes
NIHORT National Institute for Horticultural Research and Training (Nigeria)
NPQS National Plant Quarantine Service
NRCRI National Root Crops Research Institute (Nigeria)
NRI Natural Resources Institute (UK)
NSS National Seed Service (Nigeria)
OAU Organization for African Unity
ODA Overseas Development Administration (UK)
ORSTOM *Institut français de recherche scientifique pour le développement et coopération*
PASCON Pan-African *Striga* Control Network
PGI Plant Germplasm Institute (Italy)
RF Rockefeller Foundation
RRPMC Regional Research Project on Maize and Cassava (IITA)
RVAU Royal Veterinary and Agricultural University (Denmark)
SAA Sasakawa Africa Association
SACCAR Southern Africa Center for Cooperation in Agricultural Research
SADC Southern Africa Development Community
SAFGRAD Semi-Arid Food Grains Research and Development (Project)
SARI Savannah Agricultural Research Institute (Ghana)
SARRNET Southern Africa Root Crops Research Network
SDC Swiss Development Corporation
SSA sub-Saharan Africa
TARC Tropical Agricultural Research Center (Japan)
TSBF Tropical Soil Biology and Fertility Program
U University
UAC United African Company (Nigeria)
UC University of California
UI University of Ibadan
UNB *Université nationale du Bénin*
UNBRP Uganda National Banana Research Program
UNDP United Nations Development Programme
UNICEF United Nations Children's Fund
UNN University of Nigeria, Nsukka
USAID United States Agency for International Development
USDA/ARS United States Department of Agriculture/ Agricultural Research Service
UTC United Trading Company (Nigeria)
VSO Volunteer Service Organization (UK)
WARDA West Africa Rice Development Association
WECAMAN West and Central Africa Maize Network
WI Winrock International

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FRONT COVER PHOTOGRAPH/Equi Nwulu
Pollination of female plantain at IITA High Rainfall Station at Onne, Nigeria, by pollinator Christopher P. Ukpe.

BACK COVER PHOTOGRAPH/Moyo Bolarin
On-farm trials of IITA black-sigatoka-resistant, plantain-banana hybrid variety, TMPx 548/9, at Kpite near Port Harcourt, Nigeria.