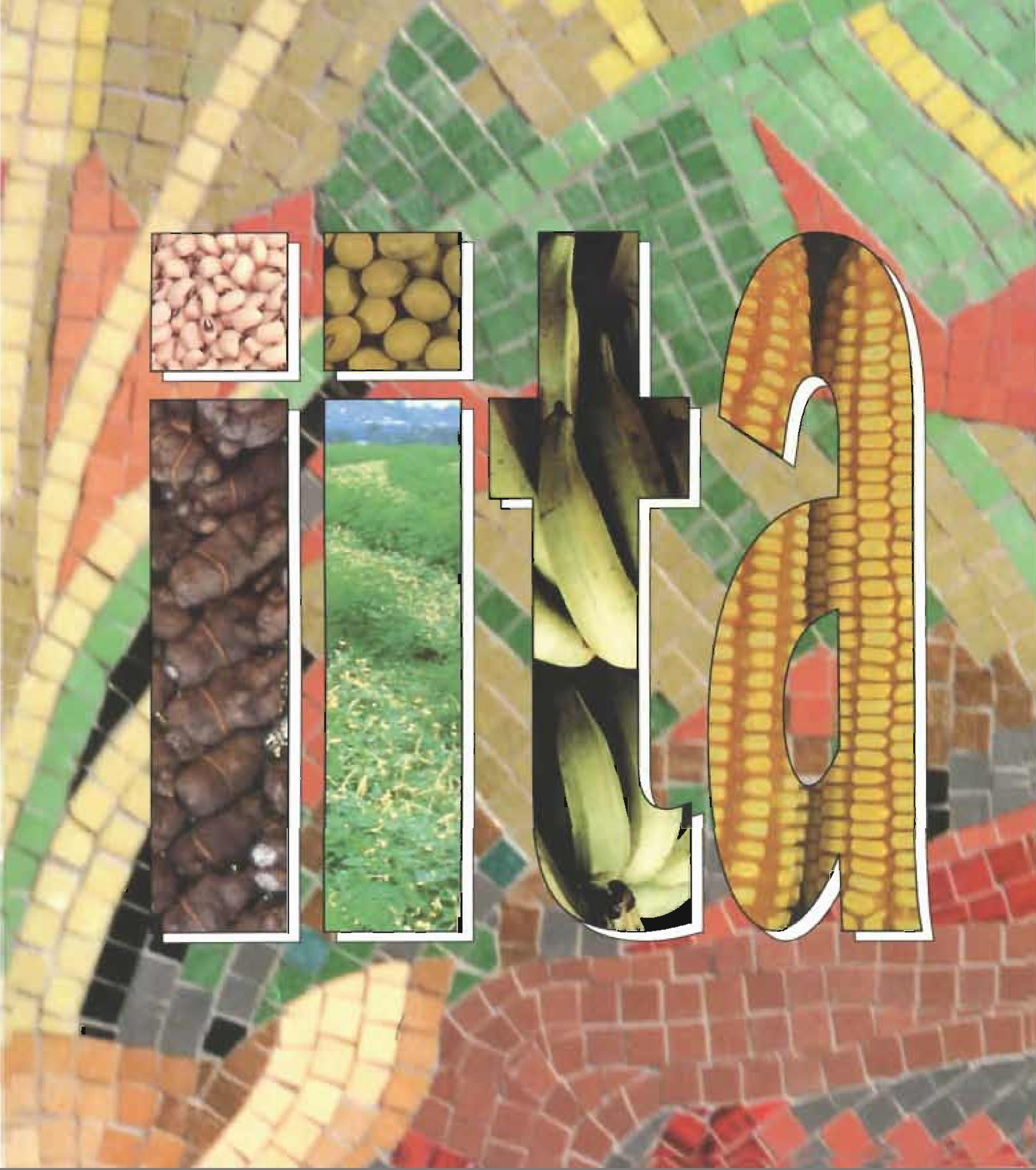
International Institute of Tropical Agriculture

Annual Report 1992



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International Institute of Tropical Agriculture

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Director General's Report

In 1992, in commemorating IITA's twenty-fifth anniversary, we reaffirmed our goals of increasingly productive and sustainable agriculture. We held a symposium on "Sustainable food production in sub-Saharan Africa" and published a book which describes our research contributions on that same theme.

Our anniversary coincides with a time of hard decisionmaking for the international agricultural research system as a whole, as some traditional donors limit their funding commitments to us in the face of new demands at home and elsewhere. It is a good occasion to take stock of our accomplishments, in the light of changing needs in sub-Saharan Africa.

IITA's twofold goal, since its inception in 1967, has been to increase production of key food crops while replacing traditional slash-and-burn agriculture with more sustainable farming systems.

We have done a good job in improving the productivity of major staples under a range of environmental constraints. Our mandate over the past 25 years has included root crops (cassava, sweet potato, cocoyams, yams), cereals (maize and rice), plantains and bananas, as well as grain legumes (cowpea and soybean). We have sought to improve yields along with plant resistance to diseases and insect pests, as well as as tolerance of abiotic stresses such as drought.

The sustainability part of our original goal, however, now presents a greater challenge than ever. While we have introduced resource and crop management technologies into many national research programs, the integrity of the resource base is increasingly threatened under the high cultivation pressure of growing populations. The need to sustain soil fertility, and to protect the farmer's gains in crop productivity, are claiming an ever greater share of the balance in the twofold goal

The validity of both the productivity and sustainability sides has been reconfirmed in the strategies and priorities recently adopted by the CGIAR as a whole. Our Medium-Term Plan (1994–1998) has been predicated on a balance between research activities that result in immediate productivity gains and those that address stability and sustainability issues in the longer term.

New plan

The proposals in the new plan, which we developed during 1992, are based on the principles outlined in our Strategic Plan and the priorities of our first Medium-Term Plan (1989–1993). The new plan has been framed in the perspective we have gained through successes and failures in recent years. The plan, together with adjustments in our management structure, allows for a balanced approach to commodity improvement and to resource and cropping systems management.

Our approach in planning for research and training activities requires that the end result should respond to the needs of the small-scale farming family. We collaborate in those activities with institutes or development

About IITA

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.

The Ford and Rockefeller foundations provided initial planning and financial support for IITA. The Nigerian government provided 1,000 hectares of land for a headquarters site and research farm at Ibadan, Nigeria. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA is governed by an international board of trustees and is staffed by approximately 150 scientists and other professionals from about 40 countries and 1,400 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, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Ghana, Malawi, Mozambique, and Uganda.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional and notional progroms in mony 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. During 1992, CGIAR contributed $249 million to their program activities.

projects of the countries that will benefit from them; and, to the extent possible, in the zone or under the specific conditions in which the results will be used. We will reinforce our collaborators' efforts to adapt and put into farmer's fields the technologies that have been developed.

Activities envisaged in the new plan are thus defined for their socioeconomic as well as physical environment to a greater degree than earlier plans have been, as a result of our growing experience in the various agroecological zones. Many of our activities during the 1994–1998 period will relate to western and central African countries. As circumstances and funding permit, we intend to extend our research activities into analogous zones of eastern and southern Africa.

Two zones will receive our most substantial efforts: the humid forest and the moist savanna. (See map on page 28.) In those zones we will collaborate in research with other international centers; for example, with CIAT on cassava, CIMMYT on maize, ICRISAT and an Italian-US-Belgian network on cowpea, and ICRAF and ILCA on resource management systems. The Global Environmental Facility is providing us with special funds to study the environmental impact of improved cropping systems vis-a-vis current slash-and-burn practices. Those funds complement the resources provided by 20 donors to our core budget.

In the mid-altitude savanna and woodlands, which are mostly in eastern and southern Africa, we expect to be able to conduct research for improvement of banana and cassava cropping systems, including pest management issues. With regard to inland valleys, which are scattered throughout the forest and savanna zones, we plan to characterize land-use patterns and to begin to develop technologies for specific types of inland valley farming systems. Together with WARDA, we will apply a "consortium" approach in working with national programs.

Humid forest

We are particularly concerned to develop sustainable farming systems that imitate the primary forest in providing for renewal of the soil while permitting continuous and more profitable cropping. They are likely to be based on perennial cash cropping with short-term cycles of food crops, in rotation with fallows of multiple uses—for food, fodder, and resource management. Such systems will have to be adaptable enough to meet economic, cultural, and environmental needs specific to the locale.

We have made excellent progress in developing improved varieties of our mandate crops for the humid forest. Beyond high yields, their value lies in resistance to various biological stresses. Healthy, disease-resistant crops, together with biological control of the cassava mealybug and other insect pests, have increased the productivity of humid forest farming. Our success with the mealybug is being repeated with biological control of the cassava green mite.

Such positive results from environmentally sound and sustainable approaches have encouraged farmers to adopt, for example, our improved maize with resistance to blight, maize streak virus, and downy mildew; and our improved cassava clones resistant to cassava mosaic virus and cassava bacterial blight. Further research will build on this work, emphasizing resistance to an enlarged range of stresses and high productivity at limited levels of external inputs.

Our experience to date with resource management systems in this zone, however, has shown how complex and difficult it is to develop alternatives to slash-and-burn cultivation, and taught us to be cautious in heralding potential success.

Moist savanna

The moist savanna or, as traditionally called, the Guinea savanna, has a higher food production potential than the humid forest zone and shows signs of becoming the breadbasket for sub-Saharan Africa. Our improved, disease-resistant maize, soybean, and cowpea varieties are confirming the zone's excellent production potential and offer a promise of fruitful research ahead. The adaptation of improved cassava clones for selected areas has begun to yield encouraging results.

It is also becoming clear that intensive monocropping systems will

Lukas Brader, Director General, IITA

not be sustainable for any length of time without measures to help maintain adequate soil fertility and counter increasing pest and weed problems. The parasitic weeds *Striga* and *Alectra* are particularly severe threats to the small-scale farmer.

Continuing progress in developing maize and cowpea lines resistant to those pests, combined with improved management practices, has helped to brighten prospects for intensified farming in the savanna. We are exploring with particular interest the use of legumes in crop mixtures or rotations, and enhanced fallow management, as areas in which new technologies can make headway against problems in the moist savanna.

Sustaining commitments

We have taken initiatives to prepare the ground for our work during the new plan period in the various zones, with careful attention to the requirements of our partners. We are mindful of their expectations, which have grown with our collaborative relations, and of the need not to jeopardize the tangible and intangible developments from those relations. We want above all to sustain our commitments and meet our objectives, if necessary through modified means, under the narrowing budgetary limitations.

The physical resources for our work plan of the next five years reside in our research facilities, some of which we have decentralized to suit activities targetted to specific zones and agroecological conditions. Our goal in decentralizing those activities has been to place the research in the areas where farmers grow the crops and where national scientists will conduct adaptive research to prepare the technologies for farmers.

The High Rainfall Station at Onne in the humid forest zone of southeastern Nigeria, and the Kano Station in the dry savanna of the north, are well established and have produced excellent results in plantain and cowpea research, respectively. The Humid Forest Station in Cameroon, which was opened during 1992, has set its agenda with sustainability research at the top. The Côte d'Ivoire government approved, in 1992, joint development of facilities for maize research in the moist savanna, at an existing national program site near Ferkessedougou.

With the major agroecological zones thus covered in western Africa, we have been developing plans for a station in Uganda with a small team for research on the main crops of eastern Africa: plantain, banana, and cassava. The government has offered use of facilities at Namulonge, while USAID has agreed to provide financial support. IITA activity in Uganda cannot, however, be fully developed without additional funding for the purpose, given current budgetary prospects.

We are complementing the decentralized research infrastructure with a system of "research liaison scientists" assigned to specific countries. They will improve communication of research needs between us and the national programs. During 1992 we made three such assignments in the Congo, Côte d'Ivoire, and Ghana.

We have also made a good beginning in decentralizing our training activities in crop management research to national programs. In decentralizing such activities, we aim to strengthen national capability in training of agricultural researchers. As a result, crop management research courses will increasingly be organized by national programs, while we will help them to develop their own training materials.

In Ghana, for example, the national program held a two-week training course in research farm management during 1992, assisted by IITA, for 20 staff from research farms. Next year, the Ghanaian agricultural authorities will organize a course for maize researchers from several West African countries, with IITA and CIMMYT support, and a course in legumes research for Ghanaian trainees, with IITA assistance.

Promoting collaboration

In promoting our collaborative activities and building up national programs, it is essential to be flexible in approach and sensitive to the particular characteristics of a problem. Political instability, or gaps between the policymaking and implementing arms of government, may exist in some countries, which affects their capability to respond to our contributions. Hence, we seek to apply the most appropriate means in preparing the way for them to benefit, in the long term, from what we can offer.

Human resources is often the area in national programs most responsive to improvement measures. That is why we have consistently invested in networking and training programs, and why we are decentralizing training activities for expanded impact. Our aim in networking and training has been to assist national programs to improve levels of conceptual thinking and technical skills. Networks for different crops and farming systems have linked key researchers of almost every sub-Saharan country, in developing their research activities through information and germplasm exchange. Our training courses have helped upgrade skills of nearly 6,500 scientists and technicians, while some 1,400 graduate degree candidates have fulfilled their research requirements using our facilities.

Over the past few years we have evolved new arrangements for collaborative research, taking advantage of improved communications and growing capabilities of national programs in all regions of sub-Saharan Africa. We have fostered the development of two new collaborative groups for crop improvement and cropping systems research: for maize and for root crops. Through on-farm research, both groups seek to strengthen proficiency in developing new approaches and methodologies for solutions, not simply testing the performance of new technologies. The member institutes of each group are working on related aspects of a common problem and meeting regularly to exchange results.

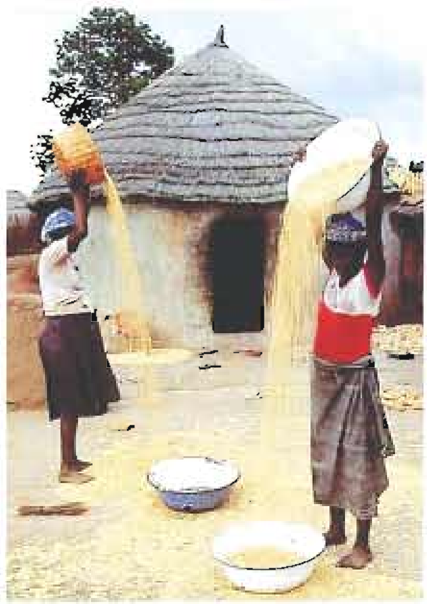
New linkages with laboratories in developed countries are enhancing our ability to translate basic research advances into technologies which sub-Saharan national programs can adapt for their own use. For example, we are working with universities in Italy, the USA, and Belgium, in a cowpea improvement project which relates biotechnological applications in crop breeding, entomology, and food science. As a result of this collaboration, and our knowledge of national program requirements, we should be able to design an improved cowpea plant that suits farmers' needs. We will also be able to bring national scientists within operational scope of this advanced research through training activities.

Linkages with donors are also providing us with the opportunity to contribute to decision-making in support of national agricultural research.

Farmer weeding his cassava, maize, and cocoyam in Ghana

During the year we actively supported SPAAR—the Special Program for African Agricultural Research, led by the World Bank—in respect of our mandated commodities and agroecological zones. SPAAR is developing a framework for action, as a basis for revitalizing agricultural research in the humid and subhumid zones of West and Central Africa.

In this critical time for the international agricultural research system, our greatest concern is to preserve the achievements and the momentum generated in strengthening of national research capabilities. The investments that have been made, in terms of capital assets, trained staff, and the body of research undertaken, are themselves like a crop that has been planted and must continue to be nourished in order to produce the expected harvest.


Winnowing maize in Ghana

Future options

The CG system is exploring new channels for disseminating research results which supplement the existing extension systems of national programs. Non-governmental organizations (NGOS) and the private sector have joined public agencies in constituting the field for collaborative action with international centers such as IITA.

This expansion of the concept of the "national agricultural research system" follows the worldwide trend of increasing reliance on non-governmental agencies for efficient means of economic growth. Many bilateral and private donors, as well as the World Bank, now tie their aid and loans to the requirement that developing countries deregulate their economies, in order to permit the private sector to enlarge its role in developing the national economy.

Agriculture is a major economic force in most developing economies. New technologies—such as those developed by the CG system—can help to enhance the power of agriculture in driving economic growth, which in turn can increase the purchasing power of the poor. Efficient, profitable farming technologies can help improve income among farmers and those in agro-related industries. Increased efficiency in food production will lower food costs, which benefits consumers as well, especially urban populations whose participation in national economies is vital to sound growth.

The job of strengthening the hand of the private sector in agriculture, in order to stimulate economic growth and help solve the poverty problem-complex, will involve changes in some of the ways we in the CG system do research and how we promote our results. At the core of our new relationship with the private sector will be the issue of differing orientations—non-profit versus profit-making—toward the ownership and use of intellectual property represented by our genetic resources and the technologies we develop from them. We must evolve equitable guidelines in order to ensure that the potentially great benefits to both sides can be realized.

The CG centers hold perhaps the largest collection of genetic resources in the developing world. Those resources, and research findings based on them such as biotechnological applications, must remain freely available to developing countries and not be removed from the public domain under intellectual property protection.

The CGIAR is therefore drafting a policy to protect the genetic resources held in trust by the various centers from being patented. CG centers are also considering a system-wide agreement that places the CG germplasm collections under FAO auspices. IITA fully supports these initiatives, and I am actively participating in the committee of CG center directors on intellectual property rights.

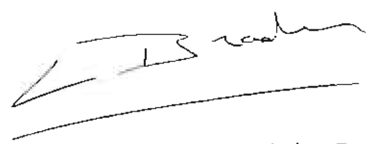
Looking beyond these developments in collaborative partnerships and genetic resources, we find many of the concerns of our own long-term agenda reflected in *Agenda 21*—the document containing the agreed aims of the international community at the 1992 "Earth Summit", the United Nations Conference on the Environment and Development (UNCED).

Agenda 21 presents program areas for each country or institution to consider for action. Program areas under section 2 of UNCED's agenda, "Conservation and management of resources for development", apply most directly to the CG system. The following five areas correspond most closely to our own research plans, those for resource and crop management:

- Sustainable agriculture and rural development
- Combating deforestation
- Managing fragile ecosystems
- Conservation of biological diversity
- Protecting the atmosphere

Resource and crop management determine how sustainable a farming system will prove to be. They are now an ever more critical part of IITA's mandate as the resource base becomes depleted under mounting cultivation pressures.

In pursuing these urgent aims, we join our colleagues in the rest of the CG system in responding to UNCED's agenda for the twenty-first century.



Lukas Brader

Research Perspectives

Promoting adoption and spread of agricultural innovations

Solutions to many of the problems besetting agriculture in sub-Saharan Africa are yet to be found. Indeed, from a scientific viewpoint, some of the problems are as yet poorly understood. A great deal of research will continue to be required in the decades ahead. And for this, international agricultural research has a vital role to play.

However, many new agricultural technologies, including improved practices and crop varieties that are vastly superior to traditional ones—products of national and international research—are already available and waiting to be used. But many of them are sitting on the shelves. They are not getting to farmers and other potential users as much as they deserve. The situation raises a major policy question: how much more research should be undertaken in the face of considerable amounts of unused research results?

Clearly, there is a strong case for the promotion of available research results, and national governments should certainly devote more resources to activities connected with promoting adoption of proven technologies and innovations. But getting research results diffused and adopted by farmers in sub-Saharan Africa is a daunting task. That is because agricultural extension services are either nonexistent or inadequately staffed and do not have adequate resources to reach farmers.

To hasten the process of agricultural development in sub-Saharan Africa, nonconventional methods of getting research results to farmers must be sought, on top of well-tested traditional approaches. An international agricultural research center does not have an easy time in defining an appropriate role in this connection. The more resources it devotes to extension-type or development activities, the greater the risk of diminishing its research effectiveness.

However, by analyzing the process of diffusion and adoption of agricultural innovations, an international agricultural research center can identify an appropriate role. This is what we at IITA have done.

"Impact", a serious concern of the international donor community and national governments, is a final product of the process of technology diffusion and adoption. Diffusion and adoption in turn depend on a large number of factors, few of which are under the complete control of researchers. Most commentators on impact would seem not to appreciate sufficiently the complex process leading to impact.

Given current interest in the impact of agricultural research, it may be useful to list the major categories of factors and outline IITA's strategy to promote adoption and spread of the technologies it develops.

One group of factors is the characteristics of the technology. A technology that is clearly profitable, reliable, and compatible with the farmer's farming systems is the more readily adopted and diffused. The more **visible** the positive attributes of a technology are to the farmer, the more likely he or she is to adopt it. In this context, a high-yielding variety has greater **visibility** than a soil-conserving technology even though, in the long term, the latter technology may be more important. It is easier for a farmer to observe a doubling of yield than an improvement in the fertility of the soil or a reduction in the soil's erodibility. Thus, impact of resource management research comes much more slowly because of its inherently low observability.

In general, scientists can do a great deal to ensure that the technology they develop has characteristics that encourages adoption. Indeed, many people think that low adoption rates are due exclusively to the failure of the technology. Therefore, they blame researchers explicitly or implicitly. But poor diffusion and adoption may be due to completely different factors. Those include economic factors—farm size, tenancy, labor, capital and credit, water availability and irrigation, prices, markets, and infrastructure.

The personal characteristics of farmers—age, level of schooling, level of technical knowledge, social class or caste, family size, and participation in organizations—are also known to be important factors. Communication, geographical, soil, and climatic factors are also important variables in the adoption and spread of new agricultural technologies.

IITA's strategy

Some of the critical factors on which adoption and impact depend are beyond the control of researchers and research organizations. Government policies and programs as they relate to infrastructure, prices of farm inputs and products, availability of credit, irrigation, land tenure, and exchange rates, among others, all affect the adoption rates of new agricultural technologies. Moreover, where extension systems are poorly developed, adoption rates of new technologies are bound to be low, and diffusion slow.

How have we at IITA sought to promote adoption and spread of our research results? First, we have continually studied both the biophysical and socioeconomic environments of African farmers, thereby ensuring that the technologies we develop are appropriate to the socioeconomic environments of farmers and are compatible with their farming systems. The technologies also address actual biophysical constraints. These characteristics facilitate adoption.

Take the case of the cassava mealybug. Our understanding of the African environment precluded chemical control. We also realized that resistant varieties, even if they could be developed quickly, would not be sufficiently rapidly adopted to solve the problem in a continent with poorly developed extension services. Hence the strategy of biological control was adopted, and its outstanding success is now history.

Farmers did not have to decide whether or not to adopt the biological control technology. They did not have to worry about capital, labor, or any input whatsoever. Poor infrastructure did not matter, and the only government policy that counted was permission to release the beneficial insects. The technology bypassed farmers and struck directly at the problem throughout Africa's "cassava belt", an area larger than continental United States.

The high-yielding varieties we have developed bypass some of the constraints to adoption, but must still reckon with the inadequate infrastructure for seed and plant material multiplication and distribution. Even when the varieties are available, there may be obstacles in the form of farmers' personal characteristics (schooling, family size, etc.), government policies, and the state of the extension system.

In trying to fit technologies to the socioeconomic conditions of farmers, IITA carries out socioeconomic characterization of farming systems as well as on-farm research. In the process of on-farm research, many farmers become familiar with new technologies which they may adopt, and then spread to other farmers. In other words, on-farm research serves an extension function through its demonstration effect.

Taking into account the relevance of soil and climatic factors in the adoption of technologies, IITA has developed and is continually refining a geographic information system. The system can help pinpoint locations where a given technology has the best chance of performing well and, therefore, where it should be promoted for adoption to generate impact.

Clearly, it is important to strengthen extension systems in order to promote extensive adoption of new technologies. Among the many problems of extension services is inadequate number of personnel with the requisite technical knowhow. It is often observed that in some countries of sub-Saharan Africa, farmers are much more knowledgeable than some of the extension agents who seek to educate them. IITA is contributing towards strengthening extension services through training. We conduct group training courses and workshops on production and other technologies for extension personnel including trainers of extension agents.

We have indicated the importance of communication in the process of adoption. Obviously, a farmer can only adopt a technology he or she has heard about and about which he or she has sufficient understanding. In an environment of weak or nonexistent extension services, communication is one area in which an international institute can play a vital and useful role.

IITA seeks to communicate its technologies through various types of publications appropriate for different categories of key players in agriculture. In recent years, we have increasingly been using the mass media—newspapers, magazines, radio, and television—to create awareness and improve the understanding of the technologies we have developed. To formalize and systematize this channel of promoting adoption and spread of new technologies, we have established the Media Forum for Agriculture. This forum is made up of media personnel as well as representatives of farmers, researchers, policymakers, extension workers, and development agencies.

The Media Forum for Agriculture has initiated what it calls the Food Action Media Service (FAMS). The service has two components—feature articles and news for newspapers and magazines called "FAMS Bulletins", and items for radio, known as "Radio-FAMS". It is encouraging the exchange of television programs of agricultural interest among television stations.

As a result of the efforts of the Media Forum for Agriculture, a number of newspapers have established "Agricultural Pages" and "Agricultural Columns". And many radio broadcasting stations now have agriculturally oriented programs in English and local languages. Consequently, agriculture is receiving much greater coverage in the mass media. And there is some evidence that this is translating into much greater awareness of technologies available to farmers—both those developed by IITA as well as those generated by national agricultural research systems.

The Media Forum for Agriculture has been active in Nigeria since 1989. In Ghana, the formal establishment of the Forum has been under discussion with the Ministry of Agriculture and the various arms of the mass media since 1992. But FAMS Bulletins are already being used extensively by media houses in Ghana.

IITA is making efforts to spearhead the formation of media fora for agriculture in as many countries of sub-Saharan Africa as possible. We hope that such media fora will become an important channel for both the international and national agricultural research systems to disseminate information about their technologies, and thus help promote adoption.

Participants at a media forum workshop visit a Nigerian national institute's television studio

Crop improvement

Crop improvement research at IITA seeks to improve the productivity of the main staple food crops in sub-Saharan Africa; and, at the same time, to ensure stability of crop production for the farmer. IITA's main concern is with breeding of improved varieties for pest resistance and for food quality characteristics which answer farmers' needs and consumers' preferences.

Plant breeders work with specialists in plant health and crop management disciplines to meet objectives set for new varieties. In problems that defy conventional breeding tactics, biotechnologists may contribute new techniques to bridge gaps in understanding.

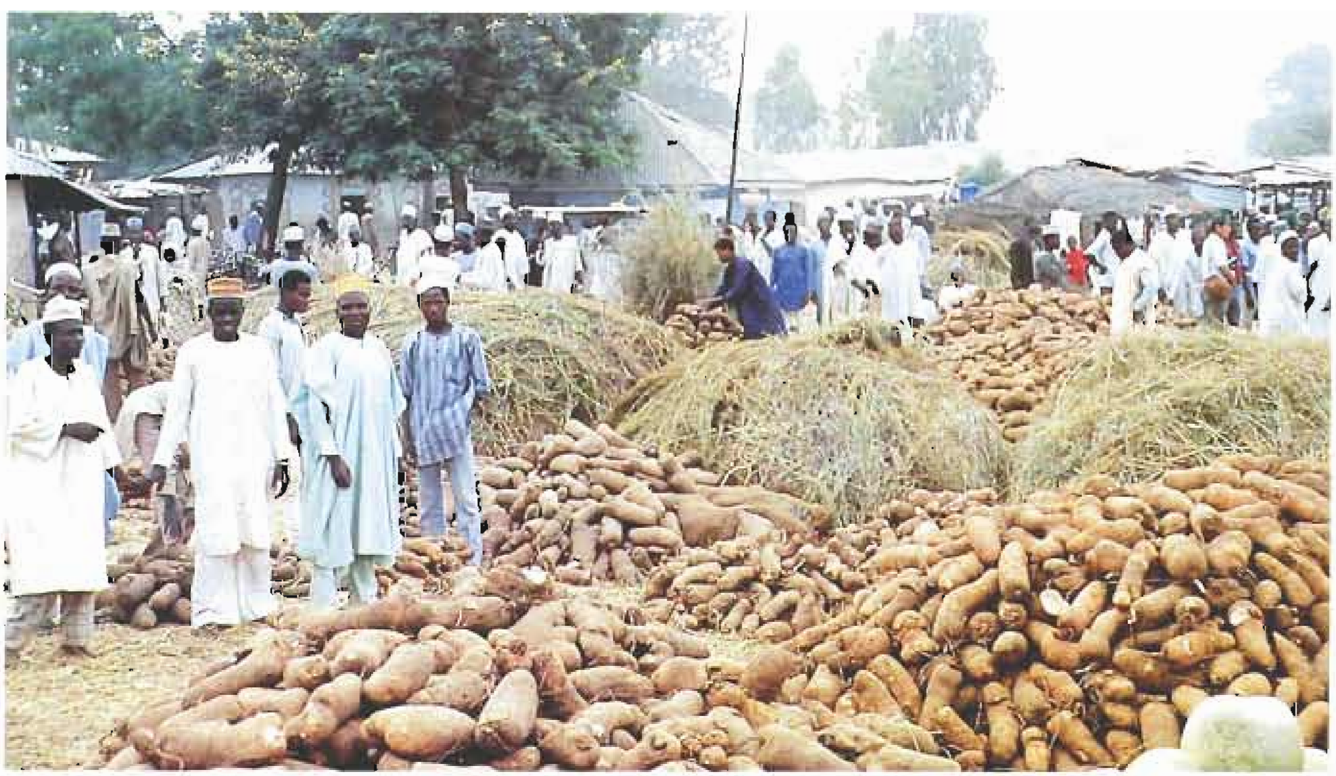
The articles in this section illustrate the range of technology and planning inputs which IITA applies in breeding.

Tissue culture triumph
The success of the year for the biotechnology research unit was the first-ever regeneration of cowpea plantlets, at a relatively high rate, with tissue culture methods. This advance has opened a new horizon for genetic transformation possibilities, particularly with pest resistance genes for cowpea, using novel biotechnological means.

No plague on plantains
IITA launched the first breeding program for plantains in Africa during 1987, mainly to produce resistance to the devastating fungal disease of black sigatoka, which was introduced into Africa during the 1970s. The genetic improvement work has succeeded beyond all expectations—several hundred hybrids between plantains and wild bananas have been produced. A first round of multilocational trials began during 1992 with 10 programs in West Africa, while a second round of advanced trials began in Africa and other parts of the world.

Better eating from cassava
More Africans depend on cassava than on any other staple food crop. IITA correspondingly devotes a large proportion of its resources to research on cassava. In breeding for food quality, the breeder's, biochemist's, and socioeconomist's viewpoints need to be considered, as well as those of the consumer.

Yam market in Burkina Faso



Major advance in plant regeneration

Biotechnological approaches to cowpea improvement made excellent progress at IITA during 1992.

Technical success in IITA tissue culture research now permits cowpea plants to be regenerated from cultured callus, a soft tissue that usually forms where a plant has been cut or damaged. The new technique can be applied in genetically transforming cultivated cowpea with desirable genes from wild species and other sources.

Regeneration

Using embryonic leaf and root parts of two cowpea lines (TVu 6202 and 83D-442, respectively), IITA tissue culture specialists first induced callus to form from the cowpea tissue in one type of culture medium, then transferred pieces of the callus to a regeneration medium in which they developed into plantlets. The results proved that plantlets could be regenerated from embryonic cowpea parts via callus cultures, in the presence of chemical solutions which promote their development. The achievement has overcome a major bottleneck in the application of biotechnological techniques for genetic improvement of cowpea. Biotechnology applications depend on plant regeneration from tissue culture as a means of actually producing the transformed plant.

Problem

Insect pests are by far the most severe constraint in cowpea production. Farmers who produce cowpeas as a cash crop may need to apply insecticides as many as three times per crop. That is expensive and can create hazards to health and the environment. Farmers who are not able to spray their crops can easily lose 90% of their potential harvest because of insect attack.

Since 1988, IITA researchers and collaborators in Italy, the USA, and Belgium have been seeking genetic affinities among cowpea's close *Vigna* relatives which will enable them to transfer genes that can confer the capability to resist insect pests. (For a summary of achievements of the international cowpea biotechnology program, see the "Research collaboration" section of this report.)

With a world mandate for cowpea improvement, IITA holds a comprehensive collection of *Vigna* germplasm which includes wild species. Scientists hope to tap the gene pool of wild *Vigna* species for traits that the cultivated cowpea lacks—in particular, for resistance to such destructive insect pests as the pod borer *Maruca* and several pod-sucking bugs. More than 8,000 lines of cultivated cowpea have been screened for resistance characteristics, with only modest success. Very good sources of such traits have, however, been discovered among wild species, particularly *V. vexillata*.

Cowpea plants can now be regenerated from cultured callus (see inset)

Insect resistance traits may take such forms as, for example, pubescence or hairiness which impedes insect attacks, insecticidal compounds, or tastes and smells which repel the pests. But the genes from wild species which express those traits cannot easily be introduced into the cowpea, because of genetic and physiological barriers to crossbreeding the species involved. The chances for successful hybridization depend, to a considerable extent, on how closely related the species are.

Breeders therefore need to enlarge their understanding of genetic affinity between the cultivated cowpea and its wild relatives, before they can succeed in exploiting the gene pool of wild relatives for cowpea improvement. To this end, plant geneticists at IITA have been studying taxonomic similarities among wild *Vigna* relatives over the past three years.

With a special focus on the problem of susceptibility to insect pests, IITA is taking two new research approaches to genetic improvement:

1. "Wide crosses" or interspecific hybridization of widely divergent genotypes of cultivated and wild *Vigna*, which confer resistance to the target pests.
2. Genetic engineering, by which foreign genes are incorporated into cowpea in order to endow progeny with the desired new characteristics.

Wide crosses

V. vexillata is one wild *Vigna* species with very hairy leaves, stems, and pods, which are demonstrably a possible source of resistance genes. IITA's past attempts at crossing *V. vexillata* and the cowpea have always resulted in the death of the embryos at the globular or early stage of embryo development.

In tackling the problem of aborted hybrid embryos, IITA is following up wide crossing with "embryo rescue", to enable the embryo to develop beyond the early stage of life. A second option was tested during 1992 whereby a complete, immature pod containing embryos was rescued by culturing on an appropriate medium. Future attempts at wide crossing with cowpea will benefit from the findings of the embryo and pod rescue studies.

Genetic engineering

Gene transfers from one species to another can also be engineered by use of *Agrobacterium* as a vector, bombardment with a "gene gun" (utilizing accelerated microparticles), or other methods, which are being explored by IITA and its collaborators at Università di Napoli, Italy and Purdue University, USA.

In attempting genetic engineering solutions, a key requirement is the ability to regenerate a plant from the cells that have been transformed with the desired new gene. Following its recent success in developing a regeneration system using callus culture, IITA plans to test genetic engineering applications during 1993. IITA biotechnologists expect to use the new technique to "grow" a plant from cowpea callus transformed with new genes through the use of *Agrobacterium* or a gene gun.

Shortcut

Purdue and IITA scientists explored another use of callus during 1992, as a shortcut for testing whether resistance genes have been successfully transferred to the plant. The rationale was that callus can be genetically transformed and evaluated more quickly than can fully developed plants. Such a procedure could save considerable time and resources that would otherwise be spent in growing transformed tissues into plants of appropriate maturity.

The experiments showed that the pod-borer *Maruca* feeds on the cowpea callus and grows. After transformation with introduced genes for insect control, callus can be tested for expression of the desired trait, as indicated through observations of feeding and growth of *Maruca*.

Black sigatoka resistant plantains on trial

Advanced field testing of IITA plantain hybrids resistant to the devastating black sigatoka disease began in 1992. The achievement marked a major success, just five years after development of the hybrids began, and a major step in the history of plantain breeding. In collaboration with IITA, over 20 national and private institutions in sub-Saharan Africa and other parts of the world have planted 13 varieties of resistant plantain hybrids in multilocational trials.

The plantain hybrids are being tested for stability of yield and resistance to black sigatoka across different agroecological conditions in West Africa (in Cameroon, Côte d'Ivoire, Ghana, and Nigeria) and East Africa (in Burundi, Uganda, and Zanzibar). The ultimate aim is to select varieties which incorporate black sigatoka resistance with high yield and other qualities desired by farmers and consumers.

Plantain production faces many problems, however. Farmers cannot easily obtain disease-free planting material. Some varieties experience rapid yield decline two years after planting and most are susceptible to nematodes and weevils. But the most important constraint in plantain production is the prevalence of black sigatoka disease.

Black sigatoka is a leaf spot disease caused by the fungus *Mycosphaerella fijiensis*, which was accidentally introduced into Africa some 15 to 18 years ago. Most cultivated *Musa* varieties are susceptible to this wind-borne fungus. Leaves develop brown streaks which grow in size, spread extensively, and turn black. Ultimately, the leaf tissue dies. In this way entire leaves become nonfunctional and, in many cases, bearing plants are left with hardly any green leaves at maturity. Photosynthesis is reduced and small bunches of fruit are produced. From one-third to one-half of the yield can be lost from infected plants.

While the disease can be controlled with fungicides, they are very expensive in Africa and could pose health hazards if incorrectly applied in household gardens. Plantain cultivars resistant to black sigatoka provide the only practical means of control.

Cooking bananas for sale along Burundi roadway

Among *Musa* species in the trials is Calcutta 4, a donor of black sigatoka resistance genes

Resistance breeding

All known plantain varieties are susceptible to black sigatoka. In 1987 scientists at IITA's research station at Onne, Nigeria, began to develop plantains with resistance to the disease. No source of resistance was known in plantains: excepting some of its *Musa* relatives, which include common dessert bananas, starchy cooking bananas, and wild species. The worst-case scenario was clearly a possibility—the loss of plantain as a major food source in tropical Africa.

Genetically speaking, plantains are triploids, having three sets of chromosomes instead of the two carried by many crop plants (which are diploids). Plantain breeding is difficult because of that fact and because chromosome sets are derived from different ancestors. Furthermore, being triploid, plantains do not normally set seed because they are infertile.

IITA plantain scientists had expected their job to consume at least 10 years. By the end of 1989, however, the future of plantains was already beginning to look bright—there had been a breakthrough in the crossing of susceptible plantains with resistant diploid bananas.

To achieve resistance, the IITA scientists needed a triploid female plantain that would set viable seed when fertilized by a diploid male wild banana with genes for black sigatoka resistance. Among the 110 different plantain cultivars maintained in IITA's germplasm collection, the scientists at first found several—by mid-1990 they had 28—seed-producing females of the preferred type.

Some so-called French plantains, that are reported to set seeds very rarely elsewhere, turned out to set an average of 5 to 20 seeds per bunch under the conditions at Onne, when fertilized with viable pollen. False Horn plantains, which had never set any seed anywhere else, managed as many as 24 per bunch at Onne. In 1988, in crossing those plantains with resistant wild bananas—disparate members of the genus *Musa*—the scientists were rewarded with viable hybrid seeds.

Using embryo-culture techniques to overcome difficulties in germination, the scientists produced some 100 hybrid seedlings, which were transferred from test tubes to field nurseries and eventually to the fields at Onne. Late in 1989 IITA announced that four of the resulting hybrid plantain plants possessed a combination of quality characteristics preferred by African consumers and high levels of resistance to black sigatoka. The resistance character results in a great delay in the onset of symptoms and slow development of the disease. Infected plants can thus mature and bear fruit normally. By July 1990, several hundred plantain hybrids were growing at Onne, awaiting evaluation for black sigatoka resistance.

Evaluation trials of the plantain hybrids for black sigatoka resistance at Onne (in the high rainfall zone of the humid forest), Ibadan (forest/savanna transition zone), and M'Balmayo (IITA's humid forest station near Yaounde, Cameroon) show (a) a stable resistance to the disease across all locations; and (b) different agronomic performance from location to location.

There are clear differences in bunch weight and fruit size. Furthermore, in the different locations there are significant differences in plant height, days to flowering, and length of the fruit-filling period. In comparison with the more susceptible local varieties, the hybrids with black-sigatoka-resistance have been the best performers for most of the agronomic characters considered.

Nigerian trials

In June 1991, Nigerian institutes began collaborating with IITA in its own multilocational trials of some of the plantain hybrids, at several locations of the country's main plantain-growing region.

A total of 10 trials over a two-year cycle have been planted in Nigeria: at IITA's Onne station and on the research farms of the National Root Crops Research Institute (NRCRI) at Umudike, in the southeast; the National Institute of Horticultural Research and Training (NIHORT) and the Federal Agricultural Coordinating Unit (FACU) in Ibadan, in the southwest; and the state ministries of agriculture or agricultural development projects in Cross River, Akwa Ibom, Enugu, and Ondo states, in the south. In the private sector, Shell and AGIP oil companies are each holding the same trials.

All the national trials were organized by an interministerial committee for the control of black sigatoka disease in Nigeria. The committee had been set up in 1987 by the Federal Government of Nigeria with a mandate to organize a survey of the black sigatoka problem in the major plantain-producing areas of the country and to propose control measures.

In particular, Nigerian trials are looking at the severity of leaf spotting by black sigatoka on the new resistant lines, and the consequent effects on plant development and yield. Early results of the trials show that black sigatoka has little or no effect on the new hybrids. In comparison with the susceptible cultivars, resistant varieties have developed normally and yielded more. Resistant varieties have also grown much faster and shown fewer sigatoka symptoms.

After those trials, the most promising entries will be subjected to one more round of tests, before final selection and release of the best varieties for distribution on request.

IITA has also sent in-vitro plantlets of the plantain hybrids to Ghana and Cameroon. The trials in Ghana are planted on the research farm of the Crops Research Institute at Kumasi, in the humid forest zone. The trials in Cameroon are coordinated by the *Centre régional bananiers et plantains* (CRBP) at Njombe, in the major plantain- and banana-growing zone of the country. For those sets of two-year trials, the assessment of growth parameters and black sigatoka severity started three months after planting. As the trials progress, IITA liaises with those institutes about data collection and analysis.

Second round

After the multilocational evaluation trials and selection of hybrids with desirable qualities, another round of breeding will be undertaken to reduce the hybrid's chromosome complements to the triploid level.

The hybrids being evaluated are tetraploids (i.e., they have four sets of chromosomes, arising from crossing of female triploids with male diploids.) Tetraploids are capable of crossing with other tetraploids, and produce seeds that are hard and unpleasant to encounter when the fruit is eaten. When reduced to triploid chromosomal status, by crossing of tetraploids with diploids, the hybrids no longer produce seeds and are thus more desirable to consumers.

Improved triploid hybrids, which the participating programs will identify as being superior, will be rapidly multiplied by shoot-tip culturing. At the end of the trials, IITA and the International Network for the Improvement of Bananas and Plantains (INIBAP) plan to multiply further and distribute the final selection of clones to national programs, which will multiply them for distribution to smallholders throughout Africa's humid forest zone.

In the East African country of Uganda, IITA is preparing for the second two-year (advanced) phase of multilocational trials at Namulonge, in collaboration with the national program. The same trials have also been set up in Burundi with the *Institut de recherche agronomique et zootechnique* (IRAZ), in Zanzibar with the Division of Plant Protection, and in Kenya with the International Centre of Insect Physiology and Ecology (ICIPE). New partners in West Africa have joined for the second phase of the multilocational trials: from Côte d'Ivoire (*Institut des forêts*—IDEFOR), Ghana (University of Ghana), and Nigeria (Plant Quarantine Service and the agricultural development projects of Imo and Abia states).

In other regions of the world, such national programs as *Instituto de investigación de viandas tropicales* (Cuba), *Fundación de desarrollo agropecuario* (Dominican Republic), and Queensland Department of Primary Industries (Australia) have requested planting materials of the improved plantain hybrids from IITA for tests in favorable environments of their own. IITA sent in-vitro materials to them for rapid multiplication and testing early in 1993.

Cooking bananas

Some varieties of cooking bananas, a distinctly different sister group to plantains, can resist or tolerate black sigatoka. In tandem with resistance breeding of plantains, IITA scientists at Onne have introduced five different cooking bananas in Nigeria. Since 1987, IITA has annually distributed about 5,000 cooking banana plantlets to Nigerian farmers and agricultural institutions for multiplication and use. The exercise has been a test of whether consumers will accept the taste and cooking qualities of those bananas, as an alternative to plantains.

The taste and texture of cooked plantain and cooking banana appear to be the same, according to a survey conducted by the Department of Food Technology, University of Ibadan. Most of the respondents in eight randomly selected villages could not differentiate between samples of the two preparations.

IITA studies have found that cooking bananas are acceptable when boiled at the green, unripe stage; but the fruits are too sweet and exhibit a very poor texture when fried at the ripe, yellow stage. Ongoing studies have found that several of the IITA hybrids have superior cooking qualities compared with cooking bananas when boiled or fried. Recent studies by IITA have found that cooking bananas attract lower market prices than do traditional plantains because of their relatively shorter fingers.

Quest for food quality in cassava improvement

IITA has conducted research on cassava since its inception more than two decades ago. It has bred cassava varieties that are high yielding and resistant to such diseases as the African cassava mosaic virus and cassava bacterial blight, which caused complete defoliation and destruction of cassava in some parts of Nigeria in the early 1970s. The success of this work was a major breakthrough in root crop improvement for Africa. Farmers who adopted the improved clones were able to increase their cassava yields by a factor of about three over local materials under heavy disease pressure. IITA has also bred varieties which have some tolerance to certain pests including cassava green mite and cassava mealybug. In addition, it has discovered spontaneous polyploids—plants with multiples of the normal chromosome number of 36: natural tetraploids (with 72 chromosomes) and triploids (with 54 chromosomes) that arose from interspecific hybridization. These polyploids, with their expanded genetic complements, tend to have greater vigor in vegetative growth than those with the normal chromosome number, and thus create the possibility of developing new and productive cassava clones.

All these achievements notwithstanding, the cassava lines developed in the early years did not possess the organoleptic properties which are normally required in food preparation in some African countries. Take the case of TMS 30572 which is favored by breeders and some farmers because it is high-yielding and resistant to major cassava diseases and pests. Some farmers have complained that it does not cook well; the tuberous roots are waxy after boiling. Hence, although it is the variety of choice in many countries, it has a lower status in areas where certain cooking qualities are a critical factor in acceptance.

Initially, disease resistance and high yield potential headed the priorities in cassava breeding at IITA. Some 20 years later, by 1989, IITA had achieved those production-oriented objectives and began to shift its breeding priorities to the suitability of improved cassava for different methods of food preparation.

Good properties

Breeders examine the following sets of plant characteristics in the cassava lines which they are considering as parent lines in creating new varieties.

1. These characteristics are especially important for consumers who like to cook and eat the cassava root as soon as possible after harvest.
- Taste (content of sugars, bitter compounds, among others)
- Potential to generate cyanide
- Texture (mealiness upon cooking)
- Rate of postharvest biodeterioration (physiological, pathological)
- Susceptibility to preharvest rind cracking (predisposes root to pathological deterioration).

The last two characteristics relate to keeping quality or "shelf life", and are critical in a country such as Uganda where consumption without elaborate processing is preferred and where fresh cassava roots command twice the price of one-day-old roots.

2. The following characteristics are important for cassava which is to be processed in various ways and kept for consumption up to several months after harvest.
- Size and shape including presence of knot-like constrictions of the tuberous root (properties which affect handling)
- Ease in peeling
- Hardness of flesh (affects ease in grating)
- Fiber content (affects quality of end product)
- Moisture content (affects time required in processing—dewatering and drying operations—and the yield of food product)
- Starch content and quality (affects the swelling capacity and stickiness or drawing power of *gari*, one of the most popular ways to prepare processed cassava)
- Color of root flesh
- Sugar content
- Enzyme activity (affects breadmaking quality).

3. For cassava leaves to be consumed as a vegetable, the following plant characteristics are examined:
- Yield of dry matter in young leaves

Roasted cassava as food in Malawi

• Capacity for quick regrowth after pruning of shoots
• Sustainability of leaf production during dry periods
• Resistance to attack by foliage pests
• Texture (suppleness) of young leaves
• Color of young leaf lamina and petiole
• Taste of cooked leaf lamina (content of sugars, among others)
• Vitamin, protein, and mineral content of the young leaf.

Breeding

To satisfy quality preference and agronomic needs in particular regions, breeding programs are organized which combine different genotypes with the required characteristics. Over the past 20 years, IITA has been using cassava varieties from many African countries which express a wide range of characteristics. In addition, IITA draws on materials available from the world cassava germplasm collection at the Centro Internacional de Agricultura Tropical (CIAT), a sister institute in Colombia. From these materials, IITA generates breeding populations with parents that are known to possess the characteristics being sought.

Seed production results from two basic types of pollination methods: "natural", with reliance on bees and other pollinating insects to do the job; and "artificial", by hand, with pollen from specifically selected parents. The artificial method affords greater control but is expensive in terms of time and labor, especially considering the large number of pollinations required. The natural method, coupled with planting of the selected parent in isolated blocks (polycross blocks) is widely used especially where selection of a number of characters is the objective.

During the growing period, seedlings are screened for resistance to major diseases and insect pests and for agronomic characteristics. Such evaluations are repeated in clonal trials over locations, over periods as long as five years, to confirm the consistent appearance of the desired characters in the selected lines. The best genotypes are eventually selected for international trials conducted in collaboration with several national programs, in order to appraise performance in related environments and conditions.

Some of the successful genotypes to emerge from the selection scheme in IITA cassava breeding programs are bred with local varieties. They serve together as parents in a hybridization scheme to combine genetic materials from different backgrounds. The resulting seed, and subsequent seedling progenies, are in turn put through the selection scheme. Sometimes it is necessary to rehybridize selections among the progenies described earlier—some important characters are inherited in such a fashion that they may not be expressed in a single generation of hybridization because they may be controlled by recessive genes. Repeated cycles of hybridization and selection (or, recurrent selection) are employed when it is known or suspected that many genetic elements, each with a small individual effect, control the character(s). For instance, IITA breeders are following this procedure in a cassava population set up specifically for good cooking characteristics and low cyanide potential.

The current practice, increasingly, is to test most quality attributes at very early stages of the selection scheme, starting from the seedling nursery for cooking quality evaluation. Standard analytical procedures, for example enzymatic assays, are used for measurable characteristics such as cyanide potential, and subjective ratings for traits, such as taste, color, and texture (feel). People familiar with the desired characteristic in the end product are asked to assess the quality expressed in each particular variety, on the basis of a rating scale.

One purpose of such an elaborate scheme is to reduce the likelihood that new germplasm with excellent agronomic traits is rejected on the grounds that it is less appropriate for food preparation than the local materials. Another is to raise the nutritional quality of foodstuff, since a lot of people in sub-Saharan Africa depend on cassava for their energy uptake.

Drying fermented cassava paste in Malawi

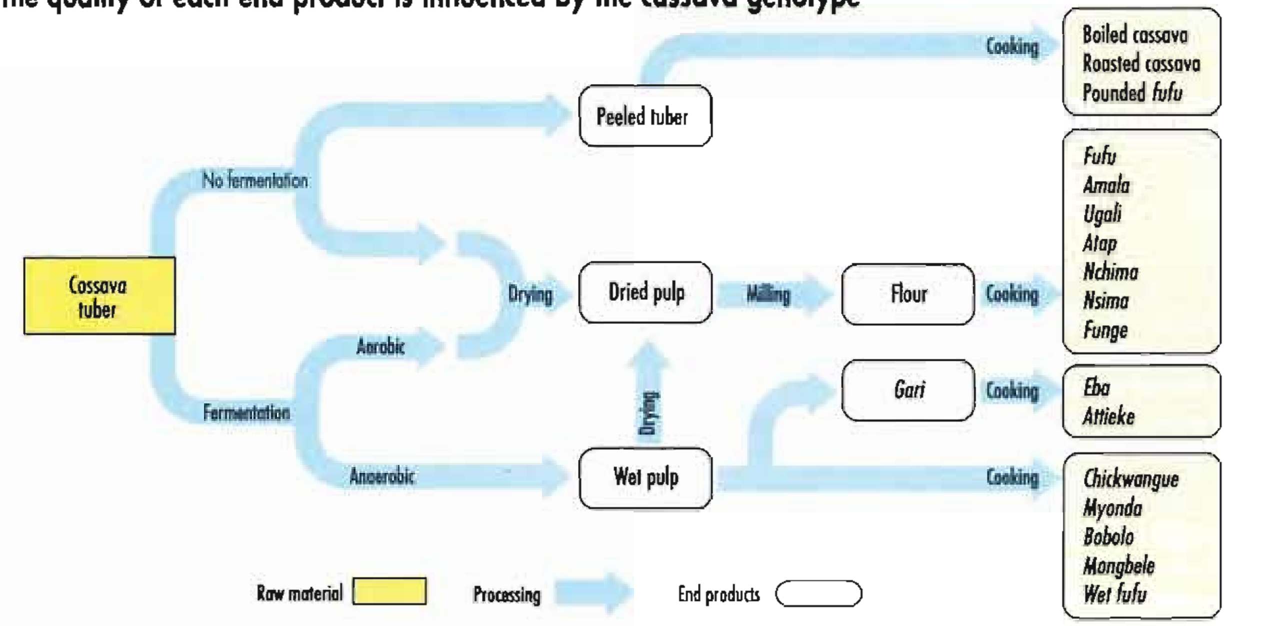
Interaction

The complexity of the selection process is matched by the complexity in defining and compiling the quality criteria to be used.

Socioeconomists, who survey farmers and consumers and learn about their food needs, collaborate closely with food technologists and other biological scientists, who identify what the desired characteristics are, and with breeders who incorporate the desired characteristics into the crop.

The cross-disciplinary interaction is continuous among these professionals, from setting the breeding priorities to analyzing the properties of the product. Such thoroughgoing interaction is

The quality of each end product is influenced by the cassava genotype



essential in the process of capturing the range of agronomic and organoleptic traits needed for the producer of the cassava root and the consumer of the prepared food.

Consumer preferences among traditional and modernizing societies may not be intrinsically difficult to assess or even satisfy. For the crop improvement efforts to succeed in an efficient manner, the problem is awareness of what constitutes consumer preferences, and how to incorporate them into a breeding strategy that provides for all requirements. No single cassava variety can suit all uses. The variability among processing properties and consumer tastes is evident in the following examples (see accompanying chart).

In Ghana, the fresh cassava roots are boiled and pounded alone or in combination with plantain or cocoyam to obtain "fufu" a strong paste or sticky dough. A similar preparation (also called fufu) is made in Nigeria by reconstituting the paste from flour obtained from dried, fermented cassava. Hence the taste or flavor of what would look very similar to the casual observer is considerably different.

Gari (grated and "toasted" fresh cassava) is a popular food in most parts of West Africa. The strong acid taste of gari is acquired through fermentation of the fresh mash. The Yoruba people of western Nigeria appreciate the flavor, but the Ibos, who make up most of the eastern Nigerian population, do not.

In Zaire where cassava leaves are very popular as a vegetable, consumers prefer leaves that are dark green and possess a level of mosaic (2–3 on a scale of 1–5) because they believe they are tastier and do not absorb much palm oil when cooked. On the other hand, Sierra Leonians prefer cassava varieties with light-green leaves, also with a level of mosaic (2–3).

Because of the rising cost of wheat flour used in bread, a popular food even among the poor of Nigeria, IITA has in the past few years experimented with possible alternatives to wheat flour. Cassava flour has shown promise as a suitable alternative. The variety of cassava used to produce this flour significantly affects the quality of bread made.

Those flours with a relatively high diastatic activity (i.e., above 150 milligrams of maltose), and low maximum paste viscosity, produce dense, pudding-like structures and are not suitable in breadmaking. Flour from varieties such as TMS 30001 can, however, replace up to 100% of the wheat flour in bread and produce a good quality of bread in terms of crumb structure and sponginess.

From feedback from different national programs and from data (including food samples from various study areas) from reports of the Collaborative Study on Cassava in Africa (COSCA), IITA has grouped the major qualities that determine consumer acceptance of cassava as follows:

- Organoleptic properties of taste, appearance, texture (mealiness) after cooking
- Potential to generate cyanide
- Keeping quality/shelf life.

Taste, appearance

The biochemical/biophysical bases for the organoleptic properties are yet to be fully elucidated. Hence, selection attributes are usually made by actually preparing the desired dishes from the different genotypes and making subjective judgements on suitability by feeling the food or using taste panels, members of which comprise persons who are familiar with the particular qualities being tested.

Data from COSCA surveys show that the color and general appearance are the most important quality characteristics for farmers in more than 50% of villages surveyed. Traditional white-fleshed cassava produces white-colored gari which is popular in western Nigeria. Yellow-fleshed cassava is preferred by the Ibos of eastern Nigeria and in countries such as Ghana, where plantain is usually pounded with cassava to produce fufu. With the increased cost of plantain, farmers prefer to use yellow fleshed cassava which gives the yellow color that would have been imparted by the plantain. In times past, palm oil would have been added to the gari during processing. Palm oil, although nutritious (containing vitamin A), is expensive and adds between 10–30% to the cost of gari prepared in this way.

From 1984–1989, IITA selected and developed some naturally yellow-rooted cassava lines from introductions from Latin America (TMS 82/01438 CB 5-80411, TMS 71673, TMS 71693). These have a high beta-carotene content (30–32 milligrams per 100 grams of cassava flesh) and in addition yield well, show low potential for producing cyanide (4.4–6.6 milligrams per 100 grams), and are fairly tolerant of cassava mealybug and cassava green mite. Some gari manufacturers in Nigeria already base their production on two of these lines, TMS 71673 and TMS 71693.

Mealiness after cooking

Another important organoleptic quality is the mealy texture of tuberous roots when boiled. Farmers in regions where "the boil and eat" type of cassava is preferred, want varieties with roots that are soft and "mealy" when cooked. The exact physiological basis of mealiness in boiled cassava is still elusive, although some association was established in 1977 between this factor and amylose content. What is known is that mealiness is strongly influenced by the cassava genotype and season (especially rainfall).

IITA scientists are breeding for mealiness. Many genotypes are currently in international collaborative trials with national programs in such countries as Benin, Ghana, Guinea, and Sierra Leone. Extensive on-farm testing of such genotypes as TMS 60142 and TMS 60140 in Uganda, a country where cooking quality is a critical requirement for cassava, have confirmed their wide acceptability. The root crop program in Sierra Leone has also made its own selections of such locally acceptable improved materials from seed populations introduced from IITA.

Cyanide potential

The issue of hydrocyanic acid (HCN) or cyanide in cassava has been a very controversial one. In Nigeria, cases of food poisoning, some of which have led to deaths, have been attributed by the media to cassava consumption. The allegations of probable occurrence of HCN in the cassava food product were not based on scientific observation.

Farmers distinguish two sets of cassava varieties.

(a) Those which can be eaten raw, boiled, or roasted in an open fire without prior transformation are conventionally referred to as sweet varieties.

(b) Those which if eaten raw, or even boiled or roasted without prior processing, are presumed to be harmful. This set is referred to as bitter varieties.

Athough the "high cyanide" varieties tend to taste bitter, some varieties have a high cyanogenic potential yet do not have a bitter taste. This finding suggests that the cyanogenic compounds are different from the factors that impart bitter taste, and that these two characters could be separated through genetic manipulation.

In areas where cassava is boiled and eaten, varieties with low potential to generate cyanide must be made available. Many varieties that have low cyanide potential, and that can be eaten as vegetable, and cut, boiled, and pounded, have been selected and are being tested by national programs of those countries where they are favored.

IITA distributes improved germplasm which provides specific characteristics to national programs with those needs, for selection under their specific local environmental conditions and distribution to farmers. Cuttings of those varieties are multiplied and distributed to farmers by program personnel in various countries. Examples of such projects include those carried out by the Rwanda National Root Crop Program largely supported by the IDRC, and the Cameroon National Root Crop Program funded by the Gatsby Charitable Foundation.

Some projects are currently being implemented in the Uganda National Root Crop Program, also funded by the Gatsby Charitable Foundation, and the Malawi National Root Crop Program, funded by USAID. In addition to accomplishing their immediate objective of transferring new varieties, those projects have provided researchers with valuable feedback, on the performance and suitability of those materials.

Distribution of improved germplasm in Africa is especially difficult in the case of cassava, because of quarantine regulations which require that new breeding materials can be introduced into a country only in the form of true seed, with appropriate chemical and physical treatments or as in vitro virus-free plantlets. So far IITA has bred over 400 genotypes that have reached the peak of the selection scheme and are awaiting evaluation by national programs. Accelerated transfer of that body of germplasm to national programs was a major preoccupation of IITA's root crops program during 1992.

Plant health management

Plant health research at IITA is concerned with the myriad interactions among pathogens or other pests, host crops, and the rest of the environment. By manipulating pest/crop/environment interrelations, plant health management scientists aim to create ecologically sustainable solutions to today's pest problems and to prevent those of tomorrow. The articles in this section illustrate both corrective and preventative approaches.

A most perplexing pest

The larger grain borer poses one of IITA's most problematical control efforts to date. This pest of stored maize abounds in several environments. The perfect candidate for a natural enemy has yet to be found. A multifaceted campaign is evolving on both sides of the Atlantic with development of a systems model, banking on IITA's success with this approach in conquering the cassava mealybug.

Model of success

The biological control program's simulation model of its campaign against the cassava mealybug explains the success of the wasp, *E. lopezi*, in control of the pest and the failure of a second natural enemy to become established. Interaction among the two parasitoids, the mealybug pest, the cassava host, and the total environment have been incorporated into the model.

Systematic problem solving

Scientists in habitat management research at IITA investigate the various environmental factors which promote or militate against healthy crop development. Habitat systems analysis provides the basic understanding of a problem that can help in restoring a favorable environment for a threatened crop. The guiding premise in selecting interventions is to use optimal means which avoid creating other problems for the people involved and the natural resources they depend on.

The built-in solution is best

Resistance breeding is the ultimate preventive weapon in the arsenal of plant health management. IITA has developed maize varieties which can resist downy mildew, a fungal disease that threatens maize crops in several parts of the sub-Saharan tropics. In Nigeria, IITA is working with the government to control the spread of the disease through genetic resistance combined with cultural controls, chemical seed protection, and training and technology transfer to official agencies and small-scale farmers.

Searching for the larger grain borer in a traditional maize store in Cotonou

Control of the larger grain borer

What the larger grain borer does to stored maize

The larger grain borer doesn't particularly need a diet of maize for survival. But when it finds a cache of dried maize, it can quickly infest the area, tunneling from grain to grain and reproducing itself to a high density. Debris from the infestation festoons the damaged grains, rendering the whole unpalatable to human consumers.

Studies on the beetle, whose species name is *Prostephanus truncatus* Horn (Coleoptera: Bostrichidae), in its native Mexico and Central America strongly suggest that it is a forest insect and is not primarily adapted to maize. However, since its accidental introduction into Africa during the 1980s, it has become a highly destructive pest of stored maize and a major threat to food security of small-scale farmers in the regions it has invaded.

An ambitious effort is needed to curb its depredations and thus preserve farmers' gains from improved maize varieties. IITA has begun to work with CIMMYT, national programs in Central America and West Africa, and European institutes, in a multipronged attack on the problem in the larger grain borer's homelands as well as its new African habitats. The approach combines investigations into the different aspects of the problem which may be manipulated to achieve control of the pest:
- the environment where the maize is produced and stored;
- natural enemies which may exist in any part of the pest's varied and dispersed habitats;
- the maize itself, and its capacity to resist the pest.

The objective is to develop sustainable and environmentally sound strategies for control of the larger grain borer. The aim is to help the small-scale farmer by reducing food losses and the environmental and health risks from excessive insecticide use.

Invasion

The African presence of this pest was first reported in Tanzania, East Africa, during 1981. In West Africa the beetle was first reported in Togo during 1984. It has since spread widely on both sides of the continent: Burundi, Kenya, and Malawi in East Africa; and Benin, Burkina Faso, Ghana, Guinea, and most recently, Nigeria in West Africa.

The introduction of this pest into Africa has resulted in a sharp increase in the already high losses of stored maize in the affected countries. Weight losses of maize over a six-month storage period in Togo were estimated to have increased more than fourfold, from an average of 7.1% before its appearance to 30.2% afterward, according to a report from the Gesellschaft für Technische Zusammenarbeit (GTZ) of Germany. Total destruction of stored maize can occur within six months, leaving small-scale farmers in a potentially desperate situation and making the traditional long-term storage of maize impractical in the affected areas.

Other African staple food commodities, especially dried cassava chips, and to a minor extent beans and groundnuts, are also subject to attack by the pest. The timber used in the construction of stores and houses can harbor populations of this pest, providing an interseasonal source for infestation of new lots of stored commodities.

On-farm losses can be substantially reduced if maize is dried, shelled, and stored in a closed granary or silo and an insecticide applied. Research on improved technology for the traditional farm setting has, however, found that such methods are not easily practicable for small-scale farmers.

Use of pesticides with stored foods, moreover, carries risks of abuse and consequent health hazards. Reliance on pesticides is apt to encourage development of strains of the pest resistant to the pesticide.

The best alternative to reliance on pesticides, apart from measures to promote improved storage technologies, is a biological control campaign against the larger grain borer which forms part of a permanent, environmentally sound system of pest management.

Biocontrol?

Being an introduced pest which causes spectacular damage, the larger grain borer should be a prime candidate for classical biological control. It should have natural enemies in its homeland which could be imported to control the pest as they do back home. Moreover, the expediency of a biological control operation is compelling—a solution with minimal or no interventions by extension agencies or farmers is attractive for a problem so widespread. The success of IITA's biological control campaign against the cassava mealybug provides an enduring model for scientists tackling other exotic pests.

The potential of one promising predator, *Teretriosoma nigrescens* Lewis

(Coleoptera: Histeridae), was first investigated during the 1990s by researchers from GTZ and the Natural Resources Institute (NRI) in the UK. Several releases of the predator have been made in Togo and Kenya and studies of establishment, dispersal, and impact are currently under way.

T. nigrescens shows a number of promising behavioral characteristics and is able to suppress pest populations in laboratory and field-cage trials. But our present state of knowledge suggests that it alone is unlikely to control the target pest adequately. Studies by IITA and collaborators at locations in Mexico and Honduras indicate that it can neither contain larger grain borer population increases in stores nor maintain losses within tolerable limits. Supplementary measures are needed to increase the impact of biological control and to integrate it with complementary strategies.

Reappraisal

New insights into the ecology and pest status of the larger grain borer have reinforced the need for a reappraisal of control strategies. A picture emerges of a pest which is very active and widely distributed, but which only invades maize stores at particular times and localities, under circumstances which are yet to be defined. Recent studies at the Kenya station of the International Institute for Biological Control (IIBC) have shown that the insect can reproduce in the wood of a wide variety of trees, including a number of important agroforestry species. In both its supposed forest and farm habitats, the larger grain borer is a highly dispersive creature, with a strongly seasonal cycle of flight activity which seems to be related more to rainfall patterns than availability of maize.

An effective control strategy for the larger grain borer thus calls for an integrated attack on several fronts. First, we need to identify the circumstances which promote severe infestations of maize—perhaps we can prevent those circumstances from coming about, through modification of the habitat or the farmers' harvesting or storage practices. We also hope to find more effective natural enemies of the larger grain borer, in order to increase the contribution of biological control to management of the pest. Finally, we are trying to breed more resistant maize varieties, which will slow the pest buildup and suffer less damage, once the pest becomes established in maize stores.

Development of an integrated control strategy for such a widespread and complex pest requires carefully coordinated research in different disciplines and geographical areas. IITA has assembled a consortium of collaborators, selected for their complementary expertise and geographical location.

In the pest's Latin American area of origin, IITA collaborates with CIMMYT in Mexico and the Escuela Agrícola Panamericana (EAP) in Honduras. Also, in both the original and adopted homelands of the pest, IITA is working on specific research tasks with national programs; for example, in Mexico with the Instituto Nacional de Investigaciones Forestales y Agropecuarias and the Colegio de Postgraduados, and in Ghana with the National Biological Control Committee.

The larger grain borer, *Prostephanus truncatus* (normal size: 3–4 mm)

African national universities (of Ghana and of Benin) and German universities (Georg-August Universität Göttingen and Technische Universität Berlin) are part of the team. Linkages have also been formed with the established research programs on the larger grain borer of GTZ, NRI, and IIBC.

The trap

With the launching of the main project in West Africa in 1992, the seasonal incidence and distribution of the pest is being continuously monitored with the help of a commercially available trap system, which is based on aggregation pheromone (a chemical secretion) of the larger grain borer. The pheromone trap is being used in three ecologically different regions of Benin: Mono Province in the southwest, Zou in the center, and Borgou farther north.

The spread in Benin of *T. nigrescens*, first released in Togo by GTZ and later in Mono Province by Benin's plant protection service, is also being closely monitored with the same trap system.

Occasional surveys with national researchers have already confirmed the presence of the pest in Burkina Faso and, with NRI help, in Nigeria. Surveys will be extended in due course to other countries believed to be at risk, such as Niger.

Preliminary studies of the population dynamics of the larger grain borer and associated species in rural stores began at a single site each in Mexico and in Honduras. Populations of all significant pest insects and their natural enemies were followed from preharvest through the entire storage season. Grain moisture content, grain damage, and weight losses were also monitored. The results should fill out a general picture of the pest status of different insects and their interactions. The results can also support analyses of the significance of such factors as inter-pest competition and natural enemy activity.

Similar studies in Benin, which include manipulation of the system rather than simply observation, are investigating the relative importance of different sources of infestation (preharvest infestation, previous infestation of the storage structure, and active migration to stores) in subsequent infestations and losses. The impact of time of harvest and various farmer practices are similarly being investigated. For instance, maize ears with good husk cover and without serious visible insect infestation at harvesttime consistently show reduced insect populations during the first months of storage. Such studies should produce recommendations for modifying farmer practices in an integrated control program.

IITA scientist inspecting a pheromone trap for the larger grain borer

The research strategy takes into account the socioeconomic variables in farming systems as well. In some cases, traditional systems have evolved successful strategies for coping with pests. On-farm surveys are therefore investigating postharvest practices and associated pest infestation by multiple regression techniques. This approach, currently being developed in Benin, is expected to be extended to regions in Mexico and Central America where farming and storage systems may have developed successful responses to attack by the larger grain borer.

Storage practices clearly differ in many respects between the pest's area of origin and its outbreak areas in Africa. Whether those differences affect the status of the pest, and whether helpful practices can be transferred from one region to the other, may be determined as a result of the current investigations. On-farm studies in Benin are examining infestation and losses in traditional stores, insect distribution within stores and the extent to which surface samples—all that can usually be collected in surveys—give an accurate estimate of infestation of the store as a whole.

Not into maize

The observation that the larger grain borer's primary host is not maize opens up possibilities for avoiding or reducing the pest through an integrated control strategy. The issues are being examined from two different angles. Populations of larger grain borer from diverse sources and locations throughout Central America are being assembled at EAP. Their performance on different substrates and their ability to interbreed is being investigated. In the second approach, IITA and their Göttingen collaborators are trying to determine whether smells direct the host-finding behavior of the pest.

Returning to biological control, the project is working on known control agents and novel and complementary candidates. In another joint IITA-Göttingen study, the predation range of *T. nigrescens* is being investigated through a biochemical analysis of the gut content of samples caught in stores and flight traps, both in the predator's Central American origin and in West Africa.

Other natural enemies found almost universally in association with larger grain borer, and with other primary pests of stored maize, are parasitoids of the family Pteromalidae. They are known from laboratory studies to have a comparatively wide host range among storage pests. However, almost nothing is known about their effect on pest populations in rural stores and the extent to which they may attack a particular species. Those questions are under study in Mexico.

New parasitoids and predators are being sought, to enhance the impact of biological control in Africa. The search is being conducted in maize stores and likely natural habitats of the larger grain borer. If the funds can be found, the pursuit should extend to fungal pathogens (jointly with the Technische Universität Berlin) and to parasitic mites of the pest (with the Colegio de Postgraduados in Mexico). The initiative on fungi appears particularly promising, in view of the joint success of IITA and IIBC with pathogens of the locust and grasshopper in West Africa. Prospective work will require innovations in application techniques; for instance, pheromone-baited traps which introduce pathogens into migrating pest populations.

Finally, work on maize varietal resistance is continuing, together with research on farmer practices and biological control. Germplasm collections have been tested by both IITA and CIMMYT in collaboration with NRI and the University of Ottawa, respectively. Some resistance in shelled grain and ears of maize, with or without husks, has been identified. The impact of these levels of resistance on the status of the pests is not yet clear, so an attempt is being made to quantify it: a selection of local traditional varieties and improved maize has been included in population dynamics studies in Benin. Any reduction in susceptibility of maize crops may help tilt the balance in the agroecosystem against the pest.

The success of this multifaceted approach depends on careful organization of the work among the far-flung team members, as well as integration of results in a telling conceptual format. The results are being incorporated in the development of a systems model, building on the success of this approach in helping to solve the cassava mealybug problem.

Simulation model explains biological control of the cassava mealybug

Our readers are probably aware that IITA has achieved considerable success in Africa in the biological control of the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr., mainly by using the parasitic wasp, *Epidinocarsis lopezi* De Santis (Hymenoptera, Encyrtidae). That effort was rewarded with the 1990 King Baudouin Award for International Agricultural Research, won by IITA jointly with the Centro Internacional de Agricultura Tropical (CIAT) in Cali, Colombia.

Impact analyses of that work, both biological and economic, have strongly documented the success of IITA efforts in working with national programs of sub-Saharan Africa to counter the threat from the cassava mealybug.

But IITA is not resting on its laurels. As an institution truly committed to research and the advancement of learning to guard against further damage from this and other threats to food production in sub-Saharan Africa, where food security is especially fragile, it continues to explore in its research the interactions of various factors involved in the biological control of the cassava mealybug, so that a reliable base of knowledge can be created for future use in other campaigns.

Successes achieved in practical application notwithstanding, the fact remains that more than 100 years of research and practice in classical biological control have not yielded a theoretical framework or model that adequately explains all the interactions involved in the selection of natural enemies for specific pests. This lack of a reliable theory, which alone can provide a predictive capability, leads to a reliance on a trial-and-error approach, an ad-hoc practice one would normally hope to avoid in a systematic endeavor. But trial-and-error methods can only be avoided as more reliable information becomes available from well-focused research specifically intended to extract such information. This is what IITA is aiming at, in collaboration with scientists at the University of Leiden, the Netherlands, and the University of California at Berkely, USA.

More specifically or explicitly, in considering the biological control of the cassava mealybug, it is important to account for the success of some parasitoid species where others have failed. Understanding the causes underlying such success and failure involves detailed investigation of related phenomena. For example, what constitutes the pest complex in cassava and what are the dynamics of those pests? After all, cassava often grows in the field for as long as two years, allowing several generations of arthropod pests to develop. In efforts at their biological control, will introducing fewer or more species of identified natural enemies, or introducing the species in a different order, help? Are the differences observed in the effects of the introduced natural enemies caused by insect biology or by environmental factors (extent of rainfall and its distribution, temperature, humidity, soil nutritional status, plant traits such as leaf size and growth, etc.) or by both? What are the interactions across those sets of factors? Studying pests and their natural enemies thus becomes a truly complex matter, especially if we are trying to achieve the capability to predict for specific situations.

This is where models come in handy. Models attempt to account for the real-world behavior of natural phenomena (in this case, insects and their natural enemies) by deliberately reducing those phenomena to a set of measurements that can help predict cause-and-effect relationships in a host-pest-environmental complex. Such models are carefully constructed from behavior observed in the past. To respond to an ever-changing situation (as in crop growth and crop production), existing models need to be studied on a continuing basis, incorporating real data from current experiments to test their usefulness and validity.

Model developed

Such a simulation model had been developed in 1988 for one exotic parasitoid of the cassava mealyhug, *E. lopezi*. It was the first species to be introduced (in 1981) into Africa in a biological control campaign, and it proved capable of keeping populations of cassava mealybug low throughout the year. By 1992, *E. lopezi* was well established in 26 countries across the cassava-growing belt in Africa, from Senegal in the northwest to South Africa in the southeast. Wherever it has been studied in detail, *E. lopezi* has been proved responsible for successful control of the cassava mealybug.

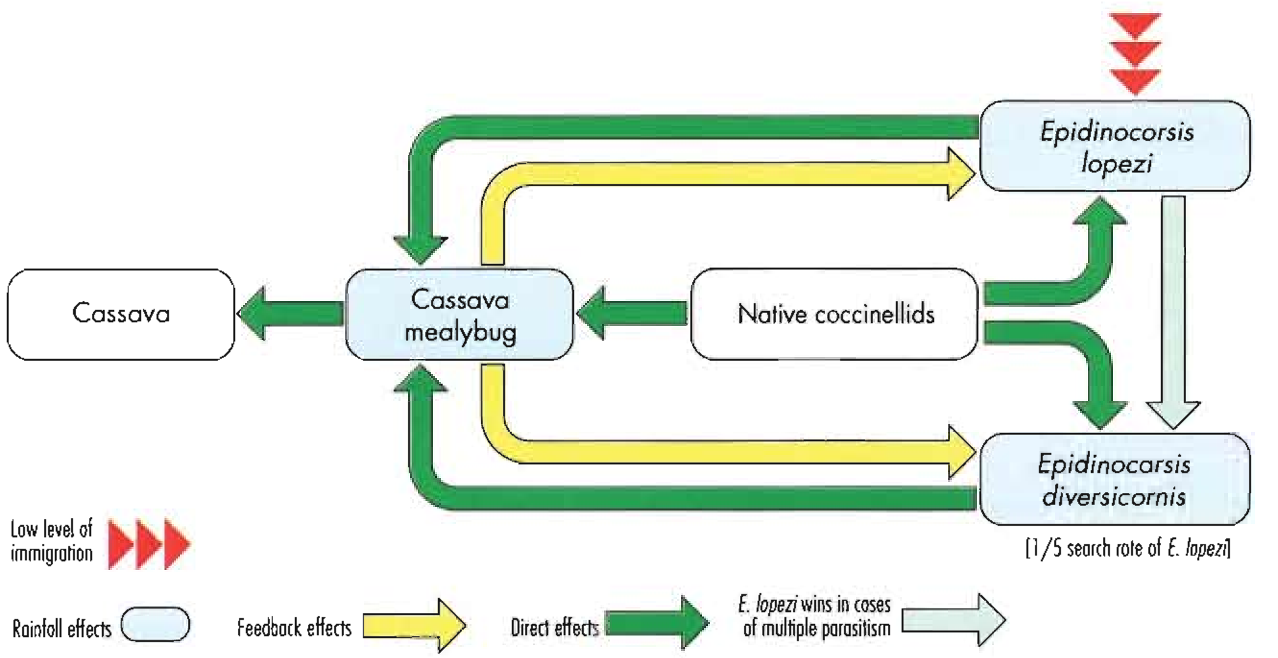
Some years after the introduction of *E. lopezi*, another parasitoid was identified and considered useful in the African campaign for biological control of the cassava mealybug: *E. diversicornis* (Howard) (Hymenoptera, Encyrtidae). The two species are taxonomically closely related, and both are known to attack the cassava mealybug in their native habitat in South America. There have been considerable differences, however, in their observed efficacy as parasitoids of the cassava mealybug in Africa.

E. diversicornis, first released in Africa in 1986, does not appear to have achieved permanent establishment anywhere, according to data available at present. Although releases of *E. diversicornis* were made in several countries of Africa several kilometers away from earlier or concurrent releases of *E. lopezi*, mummies collected one year after the releases showed the presence only of *E. lopezi*. Various factors might be related to this result: host plant and host insect incidence in the fields, plant growth or nutrition, host selection, sex allocation of parasitoids, etc.

Differences studied

The considerable differences in the observed efficacy of the two parasitoid species in Africa have been studied, to develop a working model that can

Factors considered in evolving a model for biological control of the cassava mealybug, *Phenacoccus manihoti* Mat.-Ferr.



explain the interactions and help rational choices for biological control efforts in the future. Detailed studies of the biology of the two species indicate the following:

1. Cassava plants infested with the mealybug produce a substance that attracts female *E. lopezi*, so that *E. lopezi* can find the cassava mealybug even at very low densities, an essential factor for the species to persist throughout the wet season, when the mealybug populations are low. The capacity of *E. diversicornis* to find its intended host, the cassava mealybug, has been shown in field experiments to be five times less than that of *E. lopezi*.
2. Further differences become apparent once a host colony has been found. *E. lopezi* is more successful in locating and attacking younger hosts; *E. diversicornis* either cannot find these or when it attacks them—can only produce male, not female, offspring.
3. Multiparasitism occurs: *E. diversicornis* larvae are often killed by *E. lopezi*.
4. On several other aspects investigated, there were no differences between the two species.

The model so far developed for biological control of the cassava mealybug by *E. lopezi* incorporates these results, combining laboratory and field studies, and enables weighing of the importance of different factors. The simulations gave the following important insights:

- when *E. lopezi* and *E. diversicornis* are compared, the egg-laying capacity, longevity, and food requirements of either parasitoid do not sufficiently explain why *E. lopezi* would be so superior;
- *E. lopezi*, with its efficient search for hosts, can keep mealybug density low;
- weather and soil factors (such as available water and nitrogen) affect plant growth directly and, in consequence, the size and number of the mealybugs;
- this, in turn, affects the sex ratios of the parasitoids, clearly favoring *E. lopezi*, which can produce more females on small hosts than *E. diversicornis*;
- the mealybugs are successfully controlled by *E. lopezi*; but this requires low rates of parasitoid immigration from neighboring fields;
- the higher host-finding capability of *E. lopezi* enhances its domination over *E. diversicornis*;
- by its dominance, *E. lopezi* causes the competitive displacement of *E. diversicornis* from the system. As a consequence, it did not matter in which sequence the two parasitoids were released. With *E. lopezi* released first (the reality in our campaign in Africa) or with *E. diversicornis* released and established first (hypothetically), the outcome would have been the same; and
- since the two species coexist in their native habitat in Brazil and Paraguay, *E. diversicornis* must have other, yet undetermined, hosts, probably larger than the cassava mealybug.

Given the success of *E. lopezi*, widely recognized by national programs across sub-Saharan Africa, the biological control campaign against the cassava mealybug is drawing to an end. But releases of *E. diversicornis* in the same campaign were a failure. Thanks to detailed studies and the simulation model that has resulted, we can now say why. This is an important contribution to the science of biological control, and it can be a useful tool in future campaigns against other crop pests.

Managing nature's hostility to stabilize food production

In an age of environmentally friendly technology, it may be inopportune to talk about the hostility of nature. Yet, nature places severe biological limits on crop production in Africa, especially in the form of plant diseases, insects and mites, and noxious weeds. These constraints, which are numerous, greatly affect human well-being on the continent, compounding the scarcity of food and other resources available. The harm they do needs to be duly recognized.

Curbing man's wasteful plunder of nature can be combined with combating nature's curbs on the production of foods essential to humans. Stresses to crop growth and food production can be alleviated in ways that do not erode or destroy the natural resource base for future use. Habitat management is an approach that attempts to do so, by combining host plant resistance, biological control, and cultural practices to achieve synergistic effects. It aims to avoid repeating the experience of the last two to three decades worldwide, which has clearly shown that relying on chemicals for pest control in food production is both dangerous and destabilizing.

In habitat management at IITA, plant diseases and insects are addressed mostly by host plant resistance and biological control, with cultural practices providing a valuable additional tactic for both types of constraints as well as for weeds. But there are variations in this theme. Research efforts are aimed at making coherent sense from these variations, so that the most appropriate combinations of measures can be employed for each specific crop pest. The overall goal of habitat management is to provide ecologically sound pest prevention and control strategies for small-scale or subsistence agriculture, on a sustainable basis.

Habitat management thus calls for a long-term effort, but the gains are sustainable. In addition, the approach could yield gains in the short term as well. While the immediate aim is to protect and enhance the relatively low crop yields in sub-Saharan Africa, the real power of this work lies in its ability to help stabilize crop production over time and thus create more favorable circumstances for increased investment in agriculture. Just as business corporations stay away from places where political instability and social upheaval prevail, farmers are reluctant to invest their labor and scarce capital into environments where plant diseases, insects, or weeds create a high probability that much or all of that investment will be lost.

Concerted efforts

In concerted efforts at habitat management, scientists in plant health management disciplines focus on arthropod pests, nematodes, diseases, and parasitic weeds. Resource and crop management scientists study land and water management, including weed management or cultural practices. From working within a habitat management strategy, crop improvement scientists, too, gain insights about the plant traits required for incorporation and desirable agronomic practices. Both the effort and the benefits resulting are thus multidisciplinary.

A number of measures involved in habitat management are already in practice. What is now being attempted chiefly is to put them in a systematic perspective. This is done by recognizing and actively promoting the interrelationship of three phases:

1. diagnosis of the problem, involving assessment of pest status, its taxonomy, distribution, dynamics, life tables, and the type and extent of plant damage it causes;
2. analysis of habitat interactions, such as those between (a) a crop, a pest, its natural enemies (within trophic levels), (b) a crop and alternative host plants (across trophic levels); such an analysis is best undertaken at the level of the agroecoystem;
3. identification of management strategies, involving decisions on which proportions and/or combinations of host plant resistance, biological control, and cultural practices can provide the best results.

Recent work on the bean flower thrips, *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidae), is a good illustration of this approach. The bean flower thrips is a major pest attacking cowpea at an early stage in plant development. It causes shedding of flower buds, and total crop failure can result at high levels of thrips populations.

A first step was to identify the pest and its taxonomy. First reported in Tanzania in 1905, the genus *Megalurothrips* has eight species, seven of which are found in Asia and not considered agricultural pests. *M. sjostedti* is the only species of this genus present on the African continent, and the only one that causes considerable damage to various cultivated and wild plants, including cowpea.

A second step was to analyze the seasonal abundance of the thrips, which showed that in the moist savanna zone (where a considerable amount of cowpea is grown), population levels are lower in the first cropping season (May–Jul) than in the second season (Sep–Nov). This pattern is attributable to the fact that populations in the first season crop are mainly from wild host plants flowering along the flow of waterways during the dry season, as well as from some herbaceous legumes present in or near the cropping area. These populations build up during the first crop and then invade the field in larger numbers during the second cropping season.

Parallel to these studies, a model was designed to study carbon acquisition and allocation in monocropped cowpea. The growth and development of a photosensitive cowpea variety, driven by temperature, solar radiation, soil phosphate, and water was studied to determine dry-matter attributes. The model was then used to evaluate the influence of drought stress and different levels of available phosphate in the soil.

A population model for *M. sjostedti* was subsequently superimposed on the crop model, to evaluate interactions between thrips populations and plant growth. At the same time, and equally importantly, the model was used to evaluate possible interventions with biological control.

The models thus enabled IITA scientists to derive trends or insights that can be gainfully applied in crop management. This information was supplemented by carrying out extensive surveys, which revealed three key factors responsible for the pest status of the thrips: (a) they survive on alternative host plants during the dry season; (b) although different natural enemies were observed attacking thrips eggs and larvae, their impact is too low to prevent pest outbreaks; (c) thrips larvae feeding on cowpea plants can cause complete shedding of flower buds.

That information is now being used in research decisions that affect further management of cowpea. The lack of suitable indigenous natural enemies, combined with a high damage threshold, makes *M. sjostedti* a suitable target for biological control.

Also, the fact that the thrips are found on a large number of alternative leguminous host plants means that the migration of adult thrips among the various host plants would need to be carefully understood, so that biological control and cultural practices can be used to reinforce each other in integrated efforts at pest control.

Examples

There are other examples of habitat management where a new insight or piece of information, added to existing knowledge, can considerably enhance pest control:

1. In IITA's ongoing studies on the cassava mealybug, it was found that in areas where cassava was grown on exceedingly poor, sandy soils the mealybug appeared to escape control by *Epidinocarsis lopezi*, while no damage was observed in adjacent, mulched fields. It should thus be possible to improve the efficacy of *E. lopezi* through cultural practices that enhance the fertility and water-holding capacity of the soil, thus combining several of nature's own processes to improve crop production.

2. A similar possibility is indicated for reducing infestation of the cassava green mite, though this needs further investigation. Field studies, backed up more recently by computer simulations, show that planting cassava early in the wet season makes it less prone to yield damage by this pest. There is also a clear link between soil fertility, plant vigor, and mite abundance, with the greatest yield losses from mites occurring in plants of intermediate vigor. The relationship between mite density and yield is nonlinear. Mite-infested cassava grown on soils of intermediate fertility should thus receive a high priority in research on cultural practices that improve soil fertility and water-holding capacity.

3. The role of wild grasses and sedges as hosts of cereal stem borers is not well understood. In the past, they were regarded as a reservoir for new stem borer attacks on crops such as maize, sorghum, or sugarcane. Recent studies indicate that some wild grasses are preferred oviposition sites for the stem borer, *Sesamia calamistis*, although maize—a nutritionally superior host—allows for a 10-time higher survival rate, especially when fertilized with nitrogen.

One resulting hypothesis can be that the wild hosts act as trap plants; this implies that clearing the natural vegetation and increasing the area under maize will result in greater stem borer populations. A similar situation has occurred in some locations of eastern and southern Africa, where the stem borer *Eldana saccharina* was forced from its wild hosts onto sugarcane and maize when the natural habitat was destroyed.

Parallel to this, natural enemies of maize borers are

Clockwise (from top left): an aphid-resistant cowpea developed in efforts at host plant resistance; biological control of the cassava mealybug by the parasitic wasp, *E. lopezi*; and weed management in a field, using appropriate cultural practices. Habitat management aims to integrate these approaches in a strategy that is both sustainable and environmentally safe.

exceedingly rare on maize. It is possible they lack adaptation to this host. This suggests that natural enemies to be used in a biological control program against stem borers would need to be adapted to the crop plant rather than be specific to an insect pest. Efforts have begun, both to validate these hypotheses and to search for natural enemies with a broader spectrum of crop hosts.

Viewed from another angle, habitat management consists of a series of possible manipulations to achieve intended effects. Briefly described, these are:

- manipulation of the crop's microclimate (extremely difficult to achieve, except in the laboratory or greenhouse, but potentially possible, for example, through tree-planting or afforestation programs);
- manipulation of plant structure, achievable through breeding and agronomy;
- manipulation of the agroecosystem, to make it less suitable for the pest and/or more favorable for its natural enemies;
- manipulation of available nutrition for the natural enemies;
- manipulation of the population of beneficial organisms; and
- habitat diversification, to include more natural enemies and achieve better ecological balance.

In applying these measures, a potential avenue to be explored more fully is the development of safer products, including microbial pesticides and herbicides, which consist of naturally occurring or genetically manipulated organisms. Work on this aspect has begun.

An environmentally friendly approach in our context thus means not a relaxing of the guard against biotic constraints but simply a choice of control methods that do no harm to people or the natural resources upon which their livelihood depends. And when applied in combination, these methods can be far more effective in the long run than any one control method applied alone.

Countering the downy mildew threat to maize

Boost for resistance breeding from new screening techniques

Agricultural researchers like to link the idea of crop protection with crop improvement. If resistance to pests and diseases is bred into the plant itself, protection will not need to depend on inputs from farmers who, for one reason or another, may not be able to deliver them at the right time.

Resistance breeding has been the worldwide strategy of choice particularly with maize and the fungal disease called "downy mildew". Good genetic sources of resistance have come from Thailand and the Philippines. Historically, resistance to downy mildew has been stable in improved maize which has been developed and grown in several Southeast Asian countries and in North and Central America.

Effective chemical fungicides have been developed, but they are not practical for long-term use in African agriculture because the costs and labor involved are often too heavy for small-scale farmers to bear. Furthermore, fungicides can lose efficacy over time as pathogens evolve resistance to them. All those considerations, as well as the possibly disruptive impact of chemical fungicides on the local agroecology, make host plant resistance the best solution in terms of sustainable agriculture.

Downy mildew has been recognized as a serious threat to maize and sorghum crops worldwide since the 1960s. Maize-infecting races of the pathogen in Africa were first reported during the mid-1970s. Currently, the disease has been identified on maize in areas of Côte d'Ivoire and Nigeria in West Africa; Zaire in Central Africa; Sudan and Somalia in eastern Africa; and several countries of southern Africa southward of Zambia and Mozambique.

By the end of 1992, downy mildew had invaded seven states in southwestern Nigeria, where approximately 150,000 hectares are planted to maize, or about 10% of Nigeria's maize-producing areas. The disease was spreading westward toward the Republic of Benin at a rate of about 50 kilometers per year.

Crazy tops

The symptoms can be impressive: the tassels and ears can become so deformed that the disease is often called "crazy top". More frequently, the leaves become yellowish or pale, while new leaves grow very narrow and straight. The common name of downy mildew refers to the white downy growth of spores produced by the fungus on the underside of infected leaves. In farmers' fields infected stalks emerge wanly above the healthy ones. Infected plants produce nothing to harvest.

The IITA annual report for 1975 carried the following observations:

Near Owo in the former Western State, maize downy mildew was found for the first time in Nigeria, in well-fertilized seed-multiplication plots. Examination of the area revealed that the disease was widespread and had been present for some years, but poorly expressed due to low standards of husbandry and fertilization. The disease exists for 100 miles north of the Owo area.

Since then, scientists of IITA and Nigerian research institutes have devoted much time in studying the causes and transmission of the disease in southern Nigeria and in developing resistant maize varieties. IITA's main partners in this joint effort, which has been an outstanding collaborative success, have been the National Cereals Research Institute; the Institute of Agricultural Research and Training (IAR&T) of Obafemi Awolowo University; the Federal College of Agriculture at

Akure; and the Agricultural Development Project of Ondo State at Owo.

The causal agent of the disease in southwestern Nigeria has been identified as *Peronosclerospora sorghi*. The southwestern Nigerian strain of this fungus appears to infect only maize crops; under research conditions, it does not easily infect sorghum. This same maize-infective strain is reported to have been very virulent on maize crops in central Zaire and Thailand. It does not appear to be the same strain as that in northern Nigeria, where *P. sorghi* infects sorghum.

The southwestern strain also differs from its northern counterpart in its life cycle, which does not include the "oospore" stage. This crucial difference means that the southwestern strain is not as likely to be transmitted in maize seed or in the soil. It appears to be associated only with a living host—the fungus needs to establish itself on maize seedlings which are not older than four weeks.

Apart from finding the right host, the pathogen needs the right atmospheric conditions in order to survive. Humidity is the factor most critical for the downy mildew fungus in southwest Nigeria. During the rainy season the ambient humidity permits it to flourish and reproduce, given normal levels of other environmental factors (mainly temperature and sunlight). The dryness of the air during the "harmattan" or dry season, however, will not support reproduction of the pathogen.

So how does *P. sorghi* manage to survive between rainy seasons? It can because maize is cropped in southwestern Nigeria throughout the year in different farming systems.

The hypothesis of IITA scientists and their collaborators is that the southwestern *P. sorghi* strain survives the dry season on maize farmed in the "fadama": the moist, low-lying areas known as inland valleys. In the fadamas during the dry season, moreover, farmers who plant resistant varieties may experience an infection rate of only 2–5% of their crop, which is hardly noticeable.

Once the rainy season has started, humidity builds up again across the farmlands of the southwest. And once

IITA and national program personnel inspecting "crazy top" at Akure

again the wind-borne fungal spores find a hospitable atmosphere there to do their work for the duration of another cropping season.

To counter the threat

To produce maize lines resistant to downy mildew, breeders must cross different parents with desirable genetic characteristics, until the resulting progeny bear the right combination of traits. Progeny are exposed to downy mildew spores in a test of the effectiveness of their resistance.

Those lines with the lowest numbers of infected plants under disease pressure may be selected. Since 1979 IITA breeders have selected approximately 2,000 maize lines with good sources of resistance, suitable for sub-Saharan growing conditions.

Pathologists have recently increased the efficiency of screening for resistant lines at IITA. Breeders have been able to double the volume of lines for screening and economize on use of manpower, by manipulating the biological clock of the pathogen. Lab facilities as well as field sites have been brought into play.

Screening used to entail a relatively high volume of field work at awkward hours. The pathogen prevalent in southwestern Nigeria reproduces itself asexually, by producing spores only after exposure to daylight and darkness for certain periods, under certain temperature and humidity conditions. Until recently, researchers would collect the fungal spores or conidia off maize leaves as they were produced, usually early in the morning at around 0300 hours, and then use them to inoculate maize seedlings.

In 1991, IITA pathologists were able to manipulate the periods of light and dark in the lab, following a procedure developed in Thailand. Thereafter, conidia production could be transferred to incubators in the laboratory and scheduled for daytime for convenience.

In 1992, IITA scientists developed a technique for laboratory inoculation at room temperature. The technique is applied in producing infected seedlings for infesting field trials of resistant maize lines.

It calls for a much smaller amount of conidia-bearing maize leaves than with earlier methods. The results in the screening fields provide the most consistent disease pressure yet generated at IITA. Furthermore, a key advantage is that the procedure can readily be applied in African national programs which are screening maize varieties for good sources of downy mildew resistance—incubators or other expensive equipment are not essential requirements.

Late in 1992, IITA pathologists modified a technique from Texas A&M University in the USA, for trials of resistant maize lines which are inoculated in an incubator. Conidia are collected from infected maize in the field and stored in the incubator. Two-week-old maize plantlets are placed in the incubator and inoculated with the conidia. Since virtually no "escapes" can occur in such a controlled environment, the procedure provides for a good assessment of resistance levels in the research materials. The lab procedure also doubles IITA's capacity for resistance trials, because they can be conducted in a shorter time than field trials, and they can be run year-round.

Control

It is technically possible to control downy mildew disease from southwestern Nigeria. Resistant maize seeds are available from the National Seed Service, commercial seed companies, and the state agricultural development projects (ADPs). Support for farmer participation exists in the agricultural extension system of each state's ADP. An effective and inexpensive chemical control is being marketed (a metalaxyl formulation by Ciba Geigy called Apron-Plus®).

State ADPs and commercial seed companies, which have developed in Nigeria recently with governmental support and IITA technical assistance, are distributing resistant hybrid varieties and open-pollinated varieties, both pretreated with Apron-Plus®. A sustainable and long-term solution for farmers would be to procure their seeds from either source, instead of local markets where most of the seed is of susceptible varieties.

Breeders are continuing to improve the levels of resistance in maize varieties. In the best available varieties, resistance is about 90% effective, without the extra protection of pretreatment with Apron-Plus®. Breeders are aiming to improve that level up to 95% effectiveness, and to incorporate that into a broad range of maize germplasm for different growing conditions and consumer uses.

In the field, the surest way for farmers to escape downy mildew attack is to plant their maize as early as possible in the season. Since the maize plant is susceptible only during its first three or four weeks, the crop should be planted with the first rains, before the humidity has increased and the downy mildew spores have had time to multiply and spread across the land.

In addition, elimination of infected plants from the field early in the course of the disease (about 10 days after infection, when the first symptoms appear) can provide effective protection for remaining plants. Farmers are usually in their maize fields during this time for their first weeding.

For the majority of farms at present, chemical control can usefully complement the protection afforded by resistant maize materials. As the effectiveness of resistance increases in improved maize, the need for additional chemical protection will correspondingly decline.

Task force

During 1991, Nigeria's Federal Department of Agriculture appointed a task force whose aim is to control the spread of downy mildew disease. IITA is participating together with federal and state governmental agencies for research, extension, and seed supply. The campaign combines the three classic approaches to an integrated pest management scheme—

- genetic resistance
- cultural controls
- chemical protection

—with two more:

- training and technology transfer to governmental agencies and farmers
- monitoring of the campaign's impact.

Technician prepares suspension of downy mildew spores from infected leaves

The campaign is scheduled to operate for four years beginning in 1994. It aims at "blanketing" the seven affected states with resistant maize materials, advice on cultural controls, and supplementary chemical control.

Local agencies are being provided with technologies and methods of integrated pest management in order to put the campaign on as sustainable a footing as possible. Extension specialists from the state ADPs will be trained to run the campaign with farmers.

Key to campaign success will be cultural control at farm level, through use of resistant varieties, early planting, recognition and elimination of diseased plants in the field, and reduction in dry-season cropping if nonresistant varieties are being planted.

Critical points in the control process concern treatment and use of seed. Commercial seed companies are treating the seed of resistant and susceptible maize varieties for nationwide distribution through their own or public channels. Also, ADP extension specialists will show farmers how to treat the seed that they produce each year for their next crop, and how to improve their storage arrangements.

A similar plan is being initiated with the *Service de la protection des végétaux* in the Republic of Benin, to prepare Beninois farmers for the possible arrival of the scourge during 1994.

Control measures for this highly destructive disease of maize have thus been put in place. With Nigerian public and private agencies poised to implement an integrated control program, the results of years of collaborative research are beginning to bear fruit as field action.

Resource and crop management

Resource and crop management research at IITA focuses on means to make small-scale farming sustainable, while conserving the resource base. The research is most concerned with the resources of soil, water, insolation (interception of solar radiation), farm labor, crops and fallow vegetation, and material inputs (chiefly, fertilizer and other chemicals). The articles in this section reflect those research concerns and the involvement of national programs in data collection and adaptive research.

Making more from cassava

Results from COSCA surveys are throwing light on the best options for cassava improvement, in order to enhance the commercialization of cassava farming. Findings suggest that the labor-intensive methods of traditional processing prevent farmers from taking full advantage of high-yielding varieties.

IITA nets private processors

IITA has produced a range of postharvest processing equipment for cassava farmers. A network of manufacturers has been formed to accelerate deployment of new technology and to spur local markets.

Humid forest station

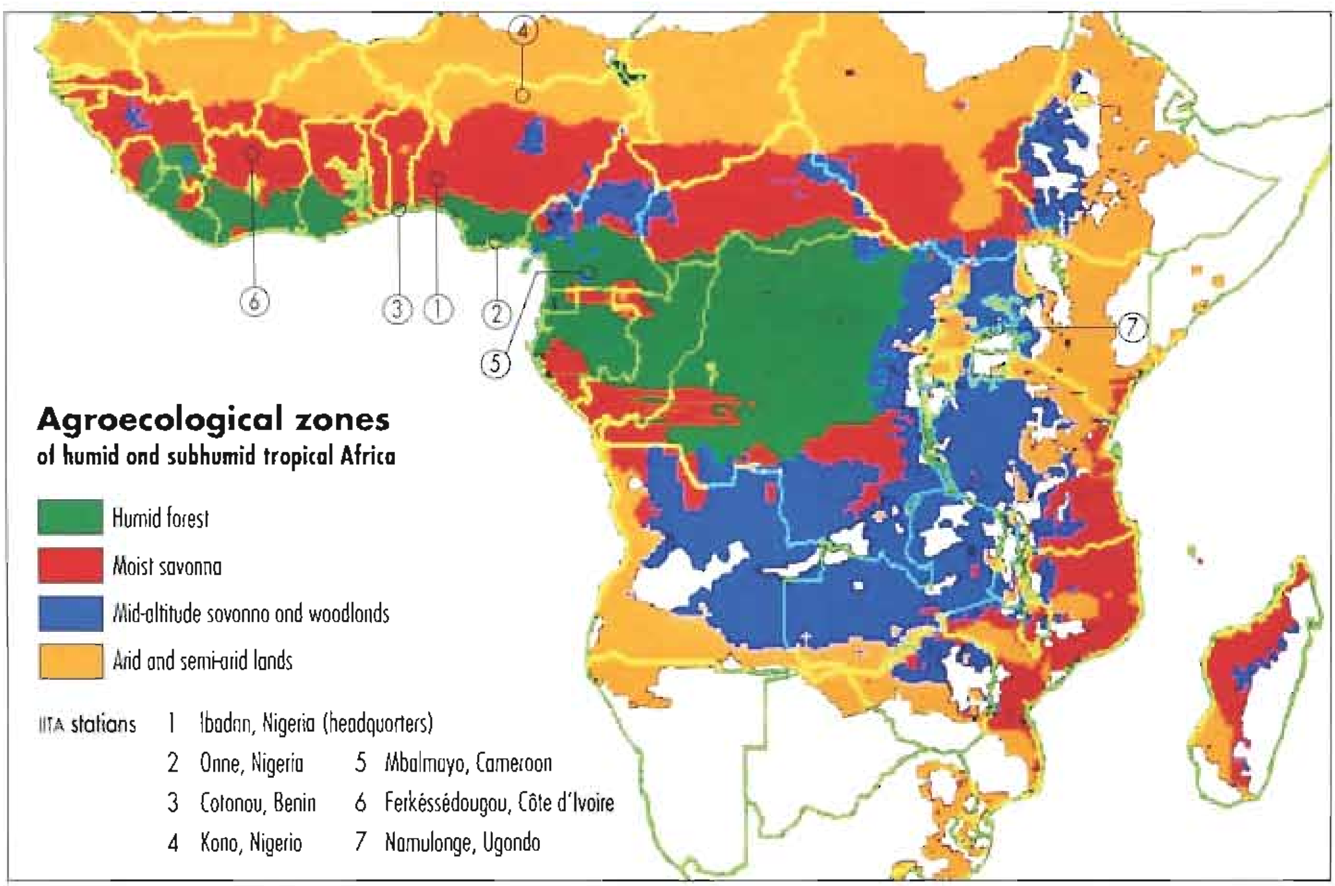
IITA's new station in Cameroon offers optimal facilities for collaborative research on Africa's humid forest zone.

The inland valley potential

Only up to one-quarter of inland valley areas are being farmed. The first steps in devising means to unlock more of that potential have been taken at IITA.

Rainfall changes

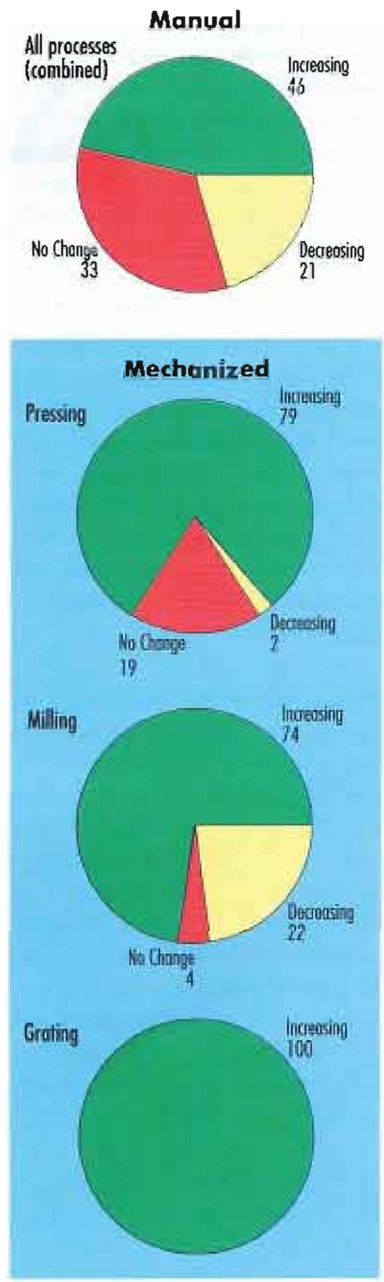
Thirty years of Nigerian rainfall data yield some insights into changing agricultural needs as a result of possible global climatic changes.



How research can help cassava farmers make the most of the market

Increasing production appears to go hand in hand with development of labor-saving processing methods. (See figure 1.) In Nigerian villages which have mechanized the grating stage in making *gari*, for example, the proportion of land devoted to cassava increases in relation with other crops cultivated. In those villages, cassava is displacing such crops as yam, millet, sorghum, and/or rice.

1. Cassava production trends in villages having manual processing vs. mechanized processing



Cassava has become a highly commercialized crop for farmers across West, Central, and East Africa. Cassava is no longer grown just for food security, to tide poor rural households over the "hungry seasons" between harvests of other crops. It is a staple food of around 200 million Africans living south of the Sahara—in some countries, Zaire for instance, cassava makes up half the daily calories consumed by the average inhabitant. It has a ready market which farmers are eager to cater for, according to their resources and accessibility to markets.

The role of research in this dynamic situation is to improve farmers' capacity to take advantage of the opportunities. Results from the Collaborative Study of Cassava in Africa (COSCA) reveal that farmers' income from cassava production is most likely to be improved through changes in on-farm processing techniques and field production methods. Technical advances that farmers need most are (a) labor-saving technologies for processing the harvested cassava roots and (b) early-bulking varieties that can be harvested within 10 to 12 months.

COSCA was organized in 1988 by a group of national and international centers and donors, led by IITA, in order to research the impact of improved cassava varieties and the economic environment of production. The founding collaborators with IITA in the study are CIAT; the Natural Resources Institute of the Overseas Development Administration, UK; the Rockefeller Foundation, which provides the basic funding; and national teams of the initial countries to participate: Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire.

Those six countries were chosen because they collectively produce 70% of Africa's cassava harvest and they could provide scientists to help execute the study. Each collaborating country has its own multidisciplinary team assigned to the study, composed of a breeder, an agronomist, an entomologist, and an economist and /or a statistician.

The first phase of the study characterizes the cassava industry in each country, from production through consumption, for which data were collected in 1989. The second phase puts together a detailed portrait of production; data collection was completed during 1991. Data for Phase III, which examines postharvest issues, were collected during 1992. Initial reports covering the six countries were completed that same year: on cassava distribution, production trends, processing potential, the commercialization potential, and the impact of improved varieties in Nigeria.

Nine other countries have since joined COSCA, widening the coverage to include southern as well as western, central, and eastern portions of sub-Saharan Africa: Burundi, Cameroon, Congo, Kenya, Liberia, Malawi, Rwanda, Sierra Leone, and Zambia. Their individual surveys were completed during 1992.

A throttle on production

Cassava production increased during the 20 years preceding COSCA in 70% of the 250 villages covered in the six original countries. Moreover, cassava production is increasing in all villages where part of the processing has been mechanized. Where traditional processing techniques are employed, however, labor becomes a constraint because peeling, crushing or grating, and toasting of the cassava roots are so labor-intensive. Increases in production are out of the question where labor for processing the harvest is scarce or too expensive.

COSCA survey in Cameroon

Among villages which produce fermented cassava products, the fermentation period is becoming shorter in 20% of them. Of those villages, the greater proportion has also mechanized the grating step in producing *gari*. They are characterized as well by good market access and high population density.

The direction for research efforts to take is clear. Availability of high-yielding cassava varieties cannot stimulate production increases without more efficient processing methods and commercialization. Improvements in processing technology should reduce the labor requirement, to enable farmers to produce and process more cassava and to sell more as a result of reduced costs.

Processing makes marketing

Fresh cassava roots are bulky, heavy, and perishable. After processing, cassava products are lighter in weight and easier to transport and store. They have a longer "shelf-life". Most products can be easily prepared for eating.

COSCA reports that about 70% of all the cassava harvested is processed into a range of food products, which includes (in order of importance) chips and flours, granules (*gari*), pastes, starch, and alcoholic beverages. To a significant degree, the importance of processing (i.e., the proportion of the cassava crop which is processed) tends to increase with the importance of cassava among all crops cultivated. That observation supports the increasing importance of cassava among all crops which accompanies mechanization or introduction of labor-saving technology, mentioned above.

Processing becomes more important for those villages with poor market access—the less accessible the market is for a particular village, the greater the proportion of its cassava crop which it processes. Therefore, the need for processing is greater in villages with difficult as opposed to easy market access.

Certain traditional fermentation methods, moreover, enhance the nutritive value of the product by increasing its protein content. Lengthy fermentation and water-expressing processes also serve to reduce the hydrocyanic potential or production of cyanide in the root flesh. Some processes impart desirable flavors as a result of biochemical changes. Those and other product qualities are benefits of traditional processing which should be incorporated in improved technologies.

Quicker harvests

A reduced growth cycle could feed the market-led trend toward expansion of production. It could also give the farmer greater flexibility in selecting crop mixtures in intercropping systems.

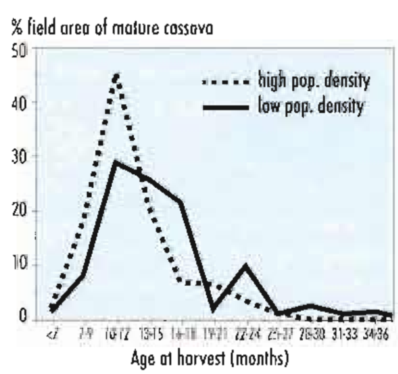
The COSCA survey in Nigeria revealed a high turnover of cassava varieties in farmers' cropping systems, indicating that farmers are seeking new varieties to fit different domestic and marketing needs. The main reason that farmers gave for abandoning any particular variety was too long a growing cycle. The message appears to be that early bulking is chief among the attributes they value in selecting cassava varieties to plant. In the survey, high yield came second to early bulking.

As commercialization grows and land use becomes more intensive under increasing population pressure, farmers need cassava varieties that can attain optimal size in fewer than the 18 months required by unimproved varieties. The typically long bulking period of local varieties was not a disadvantage when cassava was grown for subsistence or food security—when it would remain unharvested in the ground until it was needed for consumption. As the premium on land use increases, however, farmers shorten their fallow periods and seek crops with early maturities. (See figure 2.)

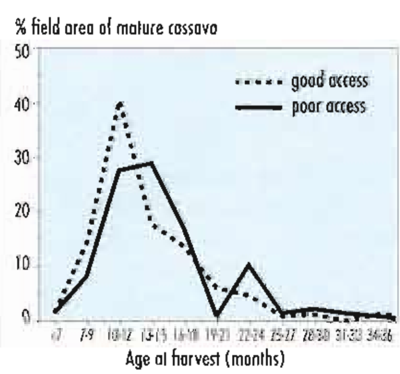
The same relation holds with market accessibility—the better the access to market, the earlier the farmer harvests the cassava. (See figure 3.)

In cassava research, COSCA sees no obvious opportunities for a technological breakthrough, comparable to the development of the high-yielding cereals of green revolution fame. The kinds of improvements farmers want to see will be those which lighten their labor and hasten their harvests, so that they can expand production to feed the increasing demand.

2. Relationship between age of cassava at harvest and population density of farming community (high or low)



3. Relationship between age of cassava at harvest and farmer's access to market (good or poor)



Equipment that ensures better use of harvests

Timely harvests and efficient postharvest operations play a crucial role in the lives of farmers. Appropriate equipment to carry out these operations reduces crop waste and enables more complete utilization of the food crops grown. This is especially true for farmers who are stepping beyond the subsistence stage to farming that can generate income.

Realizing this, IITA scientists have over the years devoted attention to designing and fabricating improved equipment. In recent years, they have focused their efforts on the cassava grater, dewatering devices, sifters, stoves, chipping machines, grain threshers, winnowers, and grinders.

While the primary goals have been to minimize crop losses and improve labor productivity and product quality (which, in turn enhance the welfare of rural women and children), activities that have evolved recently include on-farm testing and demonstration of the equipment, training of manufacturers, and networking to promote the use of improved equipment.

These objectives and activities stem from a conviction, supported by evidence, that in improving the quality of farm products, they also help raise incomes and standards of living for farm families who use the improved equipment.

As reported earlier (*IITA Annual Report 1990*, pp. 12–13), a survey in Moniya village near Ibadan, Nigeria, revealed significant gains from using improved equipment for processing cassava: a doubling of incomes, resulting from a 72% reduction in processing time and a 55% cut in handling losses.

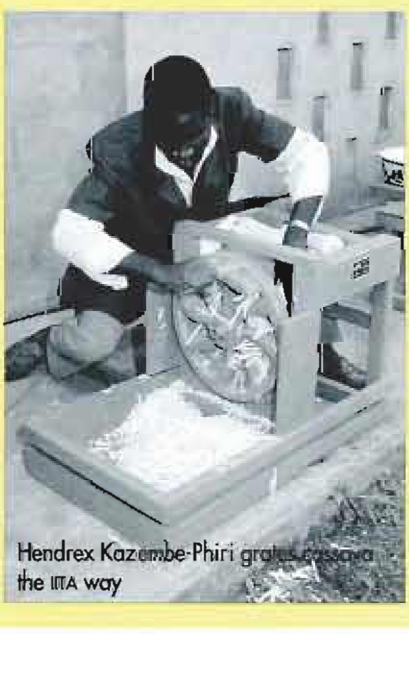
To test whether that insight is applicable on a larger scale, IITA has extended on-farm testing and evaluation to 13 sites in 5 African countries: Nigeria (8), Benin Republic (2), Ghana (1), Malawi (1), and Togo (1). These sites also serve to demonstrate the equipment being tested and to train people in its use. As a result, demand for the equipment is growing, from individual farmers, as well as from private entrepreneurs (fabricators of equipment) and food processing industries (small or intermediate scale).

To help meet this demand, IITA scientists organized a two-week training course in Feb 1993 for manufacturers working with national programs. Eight technicians or agricultural engineers—representing as many manufacturers in Nigeria—and one agricultural research officer (from Malawi) attended. The trainees gained hands-on experience. Each was expected to fabricate at least one piece of equipment identified as most useful in his locality. Most of them were so enthusiastic and dedicated that they fabricated at least two, with some fabricating as many as four pieces of equipment.

A network of manufacturers has been formed. IITA scientists and the manufacturers have worked out modalities of cooperation to ensure that quality specifications are observed and farmers will have access to the improved equipment. National programs, who are closer to the farm-level reality than can be expected of IITA, will form an important part of the network.

One key consideration in selecting each piece of equipment, in addition to its simplicity and versatility, is its reliance on inexpensive, locally available materials and fuel (or power) sources. It must also be easy to operate and maintain.

The equipment fabricated at the training workshop, for example, included two versions of the cassava grater, one suitable for small-scale,



Hendrex Kazembe-Phiri grates cassava the IITA way

Success of Networking: an example from Malawi

In 1992, a cassava grater, a chipping machine, and a grinder designed by the IITA Postharvest Technology Unit were introduced to Malawi farmers via the East and Southern Africa Root Crops Research Network (ESARRN). These implements have helped farmers, particularly male farmers, develop a renewed interest in cassava. In the past, cassava was underutilized and neglected in Malawi because of the tedious steps involved in its processing. When grown at all, it was regarded as a woman's crop and women bore the brunt of its processing. Men preferred to busy themselves with crops that were less energy consuming and that could guarantee a steady income.

In 1993, as a result of the interest shown by the farmers, an agricultural research officer in charge of farm machinery at the Chitedze Research Station in Malawi, Hendrex W.C. Kazembe-Phiri, was sent to IITA to attend a training course on the manufacture of postharvest tools and equipment. During the course, he learned how to fabricate a chipping machine for root crops. "This machine will go a long way to help my people utilize cassava better," said Hendrex. He is back in Malawi and has started to fabricate the chipping equipment, for which there is still a high demand.

IITA activities through ESARRN have resulted in the establishment of a food processing center in Malawi, which will contain about 12 types of processing machines. Food crops such as cassava, yam, taro, soybeans, and maize will be processed at the center. The center will be provided for by ESARRN funds, while IITA will provide technical assistance.

ESARRN now plans to establish similar processing centers in Burundi, Tanzania, and Zambia.

household use, the other for larger-scale production. The smaller version, manually operated, could grate up to 50 kg of cassava per hour; it is estimated to cost N1200 (US$55 at current rates) to make. The larger version, engine-operated, had a capacity of 1 tonne of cassava per hour. It cost N3500 (US$160), considerably less than the N13,000 (US$600 approx) that machines currently in use are sold for. A manual grinder, which cost as little as N800 (US$37 approx), could be used to process dried pepper, beans, yam, or cassava into flour in areas with no electricity. A chipping machine, which could be used for several root crops, such as cassava, yam, potato, or sweet potato, as well as for plantain and banana, reduces labor dramatically (usually for already overworked peasant women), and it speeds up the process of drying the chips in the sun, resulting in products with more desirable traits.

As farm production rises and more farmers go commercial (on however small a scale), demand for such simple but efficient farm equipment is likely to grow in Nigeria and other African nations. Private entrepreneurship will likely develop to meet this need. Given their expertise, IITA scientists will continue to provide technical support and training to manufacturers, so that their capability to serve the needs of the local market can be assured.

Network member (MOORETECH) at Aba fabricating IITA equipment

IITA's new research station for the humid forest zone

With the adoption of an "ecoregional" framework for CGIAR activity, IITA has taken responsibility for research for sustainable agricultural development in three zones: the humid forest zone, the moist savanna zone, and (for crop improvement and plant health research) the midaltitude and highland savannas and woodlands. (See map on page 28.)

For research purposes, IITA has defined the humid forest zone as that region of Africa below the altitude of 800 meters above sea level, in which the growing period exceeds 270 days and the daily mean temperature exceeds 20°C during that period. Within the zone, in the Congo River basin of Zaire, lies one of the world's largest remaining rainforests. By global standards it experiences a relatively slow rate of clearing.

In fulfilling its commitment in that region, IITA signed an agreement for scientific and technical cooperation with the Republic of Cameroon on 3 May 1989. The IITA Humid Forest Station was established during the following year, and became operational during 1992.

The new station will facilitate collaboration in humid forest research among countries in the zone, which include (in West Africa) Côte d'Ivoire, Ghana, Guinée-Bissau, Liberia, Nigeria, and Sierra Leone; and (in Central Africa) Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, and Zaire. The environmental importance of the region, and the excellent research facilities are expected to attract a considerable amount of collaborative activity.

The Humid Forest Station is being developed at three sites:

- an analytical laboratory and office building at Nkolbisson, where the *Institut de recherche agronomique* (IRA) has its research facilities, in the environs of the national capital, Yaoundé.
- a research farm at Mbalmayo, about 40 kilometers south of Yaoundé, on a 1,000-hectare concession within a national forestry reserve where the Office national du developpement des forêts (ONADEF) conducts forestry regeneration research.
- an experimental field site of 78 hectares at Minkoameyos, near Yaoundé.

Mbalmayo is in an area which is undergoing rapid agricultural and socioeconomic change, influenced by the expanding markets and changing demography of the capital city Yaoundé. The site offers an excellent potential benchmark for humid forest research. No comparable facility exists elsewhere in this zone.

A multidisciplinary team of researchers has been assigned to the Nkolbisson and Mbalmayo sites, composed of two soil chemists, one soil physicist, one weed scientist, and one agricultural economist (yet to be recruited). Additional IITA staff at other locations collaborate to varying extents in the work of the station.

Issues. Research at the station will address problems of declining soil fertility and increasing weed pressure as cultivation becomes more intensive with shortened fallow periods.

Population growth, especially in urban areas, has increased demand for food crops. The normal production cycle has been accelerated in many parts of the zone, reducing fallow periods and degrading the soils.

Farmers need to have the means to stabilize and increase their crop production. The goal is to develop technologies which can sustain increases in crop production without degrading farmlands. Sustainable cropping systems must be evolved so that small-scale farmers do not need to continue to clear the forest in order to find fertile soil. Farmers must be able to produce satisfactory harvests on land they have already cleared, if destruction of the remaining forests in the zone is to be arrested.

The analytical laboratory at Nkolbisson, Yaoundé, the capital of Cameroon

For more than a decade, IITA has researched basic processes of soil conservation and agricultural sustainability for the humid forest zone. Some component technologies have already been developed at IITA's High Rainfall Station at Onne, Nigeria. Work at the new Cameroon station will have a headstart by incorporating those technologies and other findings in research activities.

Researchers at the new station are aiming to reverse the decline in agricultural productivity by improving small-scale cropping systems for the forested zone. They will work with national institutions in adapting technologies to local requirements. On-farm testing will determine whether new technologies (a) can be easily adopted by farmers and (b) improve productivity and contribute to sustainability.

Current thinking holds that improved technologies may include the following features:

- cropping cycles with short managed fallows of multipurpose species
- crop mixtures of perennial cash crops with food crops
- long-term measures to sustain soil fertility, involving leguminous tree species and soil amendments to counter the acidity typical of soils in the zone.

Humid Forest Station farm office at Mbalmayo, Cameroon

Tree crops are considered essential as a means for sustaining soil fertility—mimicking the original forest which created the fertile growing conditions that the farmer seeks. But they must also have an economic value to attract the interest of farmers in introducing them into the farming system.

Preliminary research has commenced which will provide the basis for developing such technologies. This strategic research includes characterization of the farming environment, assessment of the efficiency of present farming practices, and modelling of agronomic and economic performance.

A soil survey of southern Cameroon was completed in 1992 with support from the Australian International Development Assistance Bureau. A vegetation survey of the site has commenced with the help of the Cameroon National Herbarium and two Nigerian universities: the University of Ibadan and the Obafemi Awolowo University at Ile-Ife.

Two institutions in Cameroon are collaborating with the Humid Forest Station: IRA and the University Center at Dschang. The Collaborative Study of Cassava in Africa (COSCA) has conducted the Cameroonian survey with assistance from the station. The Collaborative Group for Root and Tuber Crop Improvement and Systems Research (CORTIS) will be coordinated from the station and develop regional projects on the integration of legumes in cropping systems.

Global benchmark. At the invitation of the United Nations Development Programme, several national and international organizations, including IITA, have submitted a proposal entitled "Alternatives to slash-and-burn". The aim is to help reduce global warming, conserve biodiversity, and alleviate poverty by promoting the development of alternatives to slash-and-burn agriculture.

Eight benchmark sites have been chosen in a global network for intensive study, including the humid forest region of southern Cameroon. The IITA Humid Forest Station will take the lead in coordinating research activities between participating institutions in the region.

Inland valleys in Africa explored for their food production potential

In the manner of a city planner who has to look at a city district or zone rather than at individual houses, or of a landscape architect who looks beyond individual shrubs or trees, an agricultural planner needs to look at total agroecosystems. Inland valleys are one such agroecosystem on which IITA has expended considerable effort over the past two to three years, with encouraging results.

In trying to solve complex problems of the real world, scientists sometimes pick up pieces from the immediate reality, and add them up to make a larger picture that characterizes the system as a whole. Such a characterization provides a solid basis for understanding the constraints of the system, and then resolving them gradually through appropriate technological practices. IITA scientists have carried out such characterization work for the inland valleys of sub-Saharan Africa, in collaboration with other international agencies and national institutions in the region.

Inland valleys form a particular category of wetlands. They are relatively narrow and shallow valleys that occur in the upper reaches of watersheds. They provide a high-potential production environment for food crops. In sub-Saharan Africa, such a valley can extend up to 25 kilometers in length, and its width can vary from about 10 meters in its upper levels to about 800 meters in its lower stretches. Farmers cultivate both the valleys and the upland fields.

Three hydrological processes converge in the inland valleys: seepage, runoff, and vertical fluctuations in the water table. Topsoil lost through erosion that has occurred upland is often found in the valleys, making their soils more fertile. Numerous crops—rice, sugarcane, cassava, yam, sweet potato, maize, legumes, vegetables, banana and plantain, among others—are grown in these valleys, and their potential yields are much higher here than in upland fields (rice, for example, yields 4 vs. 1.5 tonnes per hectare). The presence of adequate soil moisture during part of the dry season probably explains the wide diversity of crops grown.

Despite this high potential, only an estimated 10–25% of inland valleys is used for cropping. Reasons for this are not fully understood yet. Human diseases are widely prevalent in these areas, perhaps accounting for their being thinly settled. Clearing the natural vegetation and developing land for farming is difficult. Numerous other problems have been mentioned: erosion, induced by runoff water; decreasing soil fertility; iron toxicity; pest outbreaks; and weed infestations (which, in some cases, reduce yields by up to 60%), among others. The physical variability of the valleys, too, tends to be high.

Past research on inland valleys in Africa has focused almost exclusively on rice cropping. Often, the implicit assumption was that the irrigated rice paddies of Asia could—or should—simply be reproduced in Africa to repeat the green revolution. It has been clear from experience for two decades now that this will not happen.

In order to understand why and, more importantly, to also understand how the inland valleys can be best tapped for food production on a sustainable basis, it was necessary that a systematic effort be undertaken to define the valleys and their characteristics in a practical, meaningful way. Strategic information was needed on the types of inland valleys, the crops grown on them, and the types of technological improvements that would be sustainable both ecologically and economically. Past research often neglected either aspect on account of bias toward the other.

A methodology had to be developed, which IITA scientists did, in consultation with specialists elsewhere (Winand Staring Centre for Integrated Land, Soil, and Water Research, in the Netherlands, and WARDA in West Africa) and with selected national programs where studies were carried out (Benin, Nigeria, Sierra Leone). Surveys were combined with various other descriptive and diagnostic tools, to build on the insights from previous experience in the region and to characterize farming systems, trace their underlying principles, and develop improved technologies that are suitable for small-scale farming.

The principal activities involved in this approach fall broadly into three categories: (a) inventory and classification; (b) quantification of constraints; and (c) design, evaluation, and testing of improved technologies (see Fig. 1).

In carrying out these activities, secondary data from numerous sources were used, within the framework of a geographical information system (GIS), often combined with satellite imagery to obtain the detailed information needed to determine land-use patterns. Ongoing efforts emphasize identification of the major types of inland valleys, so that their biophysical, agronomic, and socioeconomic traits can be verified through direct observation and other means.

So far, 12 zones (with varying agroecological and socioeconomic traits), covering 268 million hectares, have been identified, on the basis of soil type, length of growing season, population density, and per capita income. Remote sensing studies (see box) have been completed for three representative sites in the zones identified. They helped estimate the extent of inland valleys in the study areas: Kaduna (12.4%) in Nigeria, and Kabala (5.4%) and Moyamba (15.7%) in Sierra Leone. A similar effort is well under way for Savè in the Republic of Benin, and studies will be undertaken in eight other locations, spanning six other countries.

To supplement those efforts, diagnostic surveys, experiments, and process studies have been carried out at representative sites. They include studies on

- water management, to maximize drainage, using topography and rainfall;
- soil fertility, calling for soil amendments and appropriate plant species;
- weed management, to include "friendlier" vegetation, such as legumes used as cover or smother crops (in

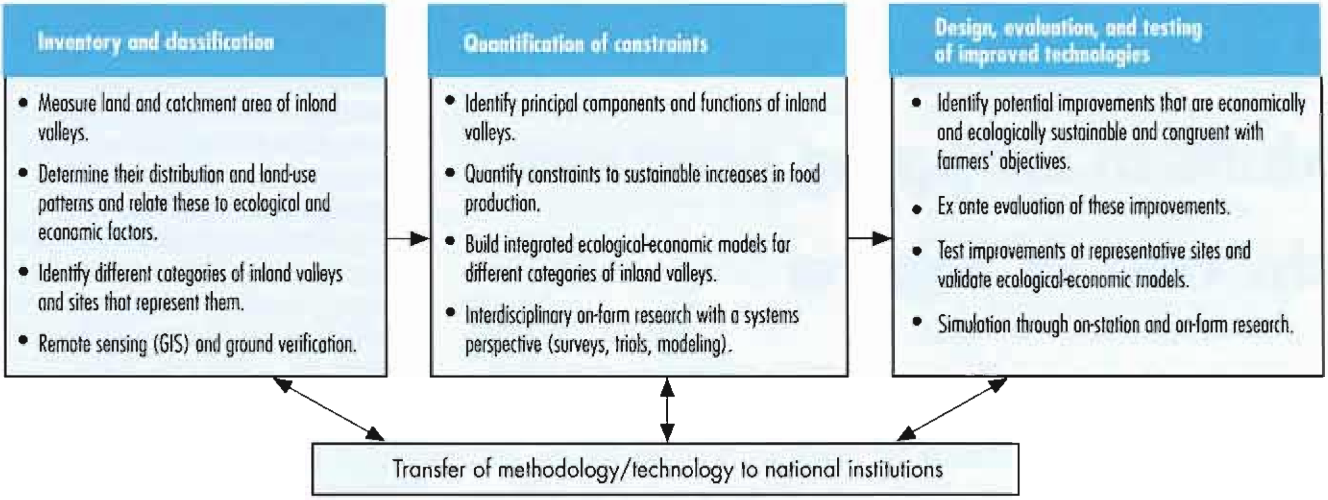


Figure 1. Principal sets of activities for inland valley agroecological research

these cases, the associated pests and diseases need to be studied as well);

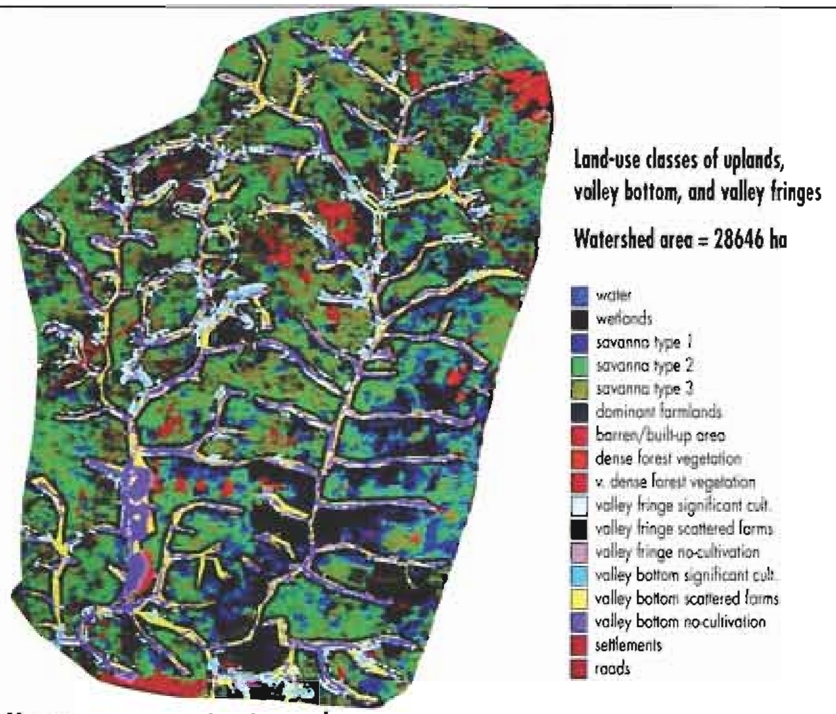
• land clearing practices, to make them less expensive for the farmer, possibly within the framework of an integrated watershed; and

• improved crop varieties, adapted to the varying needs of inland valleys.

The data so gathered will be used to build models that depict the most significant components—biological, physical, hydrological, agronomic, and socioeconomic—of the different types of inland valleys. These simulation models can then be used to assess potential technologies for their sustainability, both ecological and economic.

National institutions in Sierra Leone have taken active part in efforts related to that country. Staff of the Land and Water Development Division of the country's Ministry of Agriculture, Natural Resources, and Forests have worked with IITA scientists in developing detailed maps, based on satellite images and nationwide aerial photography already available to them. Staff of the Institute of Agricultural Research and of Njala University have been involved in quantifying constraints, and they will help in designing and assessing new technologies. The effort thus benefits from the knowledge local experts have of the predominant farming systems in the region.

IITA scientists feel confident that the method can now be used to characterize agroecosystems over a large area. The method offers two major advantages: (a) the quality of the data, and (b) the rapidity in obtaining it. Although some people might argue that satellite images (both past and present) are expensive, that cost must be weighed against the man-years saved in research to obtain the information by other means, as well as the costs involved in delaying possible solutions to impending problems of the region.



How remote sensing is used at IITA

Remote sensing, or gathering information from pictures taken by satellites orbiting the earth, is today used for a wide variety of scientific applications. In our present context, images from LANDSAT and SPOT satellites have helped gather information on where and how widespread inland valleys are, and how their land is used relative to adjacent uplands (see photo). The images have also shown the surroundings in which such valleys occur, and where and how dense human settlements and their transport networks (roads, canals or other waterways) are.

The images have been used to study watershed characteristics—such as stream density and frequency—and to estimate the soil moisture that can be used for crop production; relative soil erosion on uplands via runoff; types of vegetation; the crops grown and the stresses they face (insect pests, diseases, weeds, drought). The composite impression so gathered is then verified by detailed ground observations of selected locations (12 such locations were identified in 9 countries, see accompanying text). This process is called ground truthing.

Rainfall changes call for shifts in cropping practices: the case of Nigeria

Climate change is today a global concern. While human societies have faced up—and adapted—to dramatic changes in the Earth's climate over several millennia of human history, the dimensions of the current concern are far greater. Human activities, compounded by a rapidly growing world population, are altering the composition of the Earth's atmosphere radically in ways that could quickly bring about catastrophic changes.

Global warming, caused by the emission of greenhouse gases, is a major problem, with enormous consequences. One aspect of it that has direct implications for mankind's food supply is shifts or variations in rainfall (both its extent and distribution) in each region. This aspect has a special urgency for the peoples of sub-Saharan Africa, where per capita food availability has already declined consistently over the past three decades.

In seeking insights that can be applied to agricultural planning for the region, IITA scientists studied rainfall in Nigeria over a 30-year period (1961–1990), using rainfall data available with Nigerian national programs. The study yielded several interesting results, which can be summarized thus:

• Using each decade as a unit of comparison, annual rainfall during 1981–1990 declined from that in 1961–1970. While there were variations in the extent of decline, the decline was universal.

• The greatest changes occurred in the onset of the rainy season and the extent of early rainfall; this increases risk in planting.

• Isohyets (which are lines joining areas of equal rainfall on a map) at the annual levels of 900, 1100, 1300, and 1500 millimeters steadily shifted southward (see accompanying figure), emphasizing the need to re-examine the suitability of crops being planted.

• The available crop growing period was generally shortened by nearly one month.

• There were fewer wet days and higher rainfall intensities throughout the country; this causes erosion and emphasizes the need for improved measures to arrest erosion (land cover, better soil and water conservation methods).

• Persistence of the current trends would mean drier areas and more deserts in the long run.

Arresting or reversing those trends, if at all it is possible, would depend upon what is done to deal with them—by researchers, policymakers, agricultural planners, and farmers alike.

But before considering what can be done, in either the short or the long term, it may be useful to examine those findings in greater detail, including some hurdles that had to be faced in designing the research and some methodological choices that were made.

While long-term trends in rainfall in Nigeria have generally been well documented by scholars in the region, data-gathering efforts in recent decades have been hindered by faulty equipment or by civic or political disturbances (such as the civil war of 1966–1970). Notwithstanding these problems, data were obtained from the Nigerian Meteorological Service and the Institute of Meteorological Research, Oshodi, Lagos, covering 23 key locations: 18 of them had records for 25 years or more of the 30-year period, while the others had data for 20 to 25 of those years.

IITA scientists feel the results obtained justify their decision to use a decade as a unit of comparison, departing from an earlier practice of studying 30-year or 40-year periods (or even longer), in view of the rapid anthropogenic (human-induced) climate shifts in recent decades. It also enabled a closer focus on relative changes in annual, seasonal, and monthly averages, as well as in the number of rainy days and rainfall intensities, which are particularly important for agricultural practices.

Rainfall declines

Annual rainfall has declined in Nigeria over both time and space. While reductions of 100–313 millimeters occurred, depending on topography and location, each of the isohyets mapped indicated a southward shift (toward the ocean, by 75–200 kilometers). While there appeared to be little change in total rainfall in areas with an annual mean upward of 1700 millimeters, shifts were the greatest in low-rainfall areas. This drying trend is likely to aggravate water deficits during years of real drought, as witnessed by the 1973 and 1983 droughts in Nigeria. If the trend continues, it will mean drier areas and more deserts in the long run.

Blessed with abundant solar radiation, areas in the middle belt and in northern Nigeria have a high agricultural production potential. A reduction in rainfall there, however, is likely to have serious consequences. Millions of cattle and small ruminants in the northern savanna will likely find less drinking water and face shorter grazing periods. The shift in balance between increasing dry spells and the decreasing wet season will affect the crops that can be grown on residual soil moisture. It would also render postrainy season cultivation—common on inland valley swamps within the region—extremely risky without supplemental irrigation. As is well known, irrigation facilities are scarce in the region.

Shifts in the monthly distribution of rainfall within the main rainy season were also significant. Increasingly, there has been less rain in the first month of the season, followed by a proportional increase in the second month. These shifts will likely delay planting as early planting becomes increasingly risky. Delayed onset of rains has also tended to shorten the growing season overall by about a month. This determines what crops can be successfully grown.

The risk to the region seems greater when one considers that, driven by market forces and changing consumer tastes, maize is being adopted increasingly where sorghum used to be the main crop. Maize requires more water than sorghum or millet. This increases the probability of potential crop failure in years of adverse rainfall, which, in turn, should cause concern on account of both ecological and human welfare. Witness the experience of Zimbabwe in 1992, where a devastating drought has occurred from a similar confluence of factors.

Fewer wet days in a rainy season emphasize the need to conserve water, while greater rainfall intensity requires more careful attention to conserving the topsoil, already quite shallow in many African regions. Intense rainstorms cause soil erosion; they carry away vital nutrients from the topsoil and reduce the soil's organic-matter content and water-holding capacity, thus leaving less water available to plants. Both soil and water need to be conserved.

Among strategic technologies to be developed for dealing with one or more of the adverse climatic impacts:

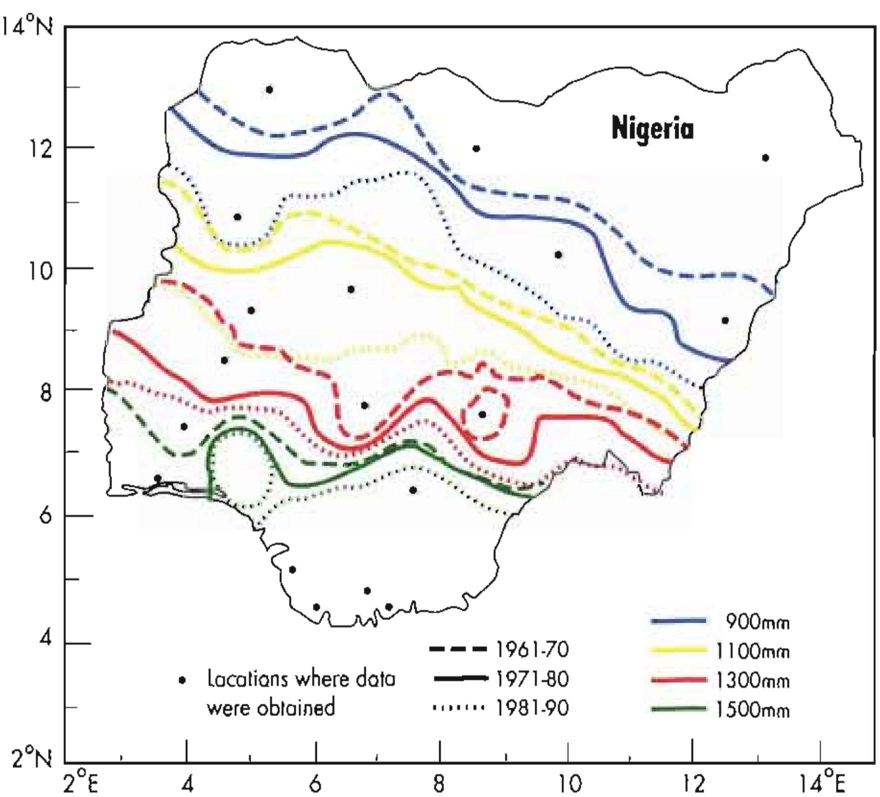
- increasing soil organic-matter content;
- making effective use of livestock wastes;
- increasing crop diversity, and choosing crops more deliberately to suit rainfall regimes;
- employing ridge planting; and
- use of trees or shrubs as windbreaks, as well as to soften the erosive impact of intense rainfall.

Those measures, taken together, could considerably lessen the adverse effects of desertification and help delay the worsening impact of global warming. The task is by no means easy. But given the political and socioeconomic problems and the rapid population growth in sub-Saharan Africa, inaction could be fatal.

IITA scientists recognize that more studies will be needed—given the sensitivity of climate—to confirm these trends, and to avoid overgeneralization. They hope that the study reported here will catalyze similar efforts in other countries, resulting in specific plans for the ecoregion, with the active involvement of national researchers.

More also needs to be done to improve research capability in the region to more accurately analyze and predict trends in climate change. A more reliable, denser observation network, with adequately functioning equipment, is required. From the data collected in the IITA and other studies, the trends reported do not appear random. But continuous monitoring will be needed to confirm or alter the diagnosis, using improved tools when and where available. Either that, or events will force upon the region a point of no return.

The changing rainfall pattern in Nigeria



Not alone

IITA scientists can take heart from the fact that they are not alone in these efforts. Several international and regional organizations (FAO, WMO, UNEP, ACMAD, CILSS, AGRHYMET) are concerned and involved in coordinating similar studies, and IITA's sister institute in the CG system, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has carried out important agroclimatological studies in a neighboring ecoregion.

Also, global warming need not be an unmixed disaster for sub-Saharan Africa. There are indications that rainfall may increase in some hilly regions. There is also the hope that warmer temperatures and increased insolation will boost crop production in the midaltitudes and elevated landscapes or highlands.

More timely and reliable information on present and future rainfall trends will reduce uncertainty, and help develop strategies that minimize the adverse effects from climate change. Since the underlying natural resource base in sub-Saharan Africa is generally so weak, the need is even greater for accurate information that can point to appropriate technologies. IITA scientists will continue their attempts to strengthen research capability in the region to more effectively tackle the problems resulting from climate change.

International cooperation

IITA's principal means of helping to strengthen national research systems are training, information dissemination, germplasm exchange, and collaborative research.

Most of IITA's research activity involves collaboration with scientists in national agricultural research institutions—in universities, governmental institutes, NGOs, and private agencies. The collaboration is designed to strengthen national programs and enhance the process of adapting improved technologies to suit farming needs in specific agroecological zones.

The following articles portray national to regionwide collaborative activities with which IITA fulfills its goals for national research development.

The SAFGRAD networking experience

The scientific establishments in 26 countries of the Sahelian region have been strengthened through networking activities during the 15-year lifespan of the SAFGRAD project. Maize and cowpea scientists developed new varieties with drought tolerance and other desired traits. Both crop networks helped increase availability of new varieties to farmers.

Training takes the farmer's perspective

Researchers, extension specialists, and agricultural trainers must be able to listen to farmers in order to understand how best to help them. To give such trainees a practical experience in communicating with farmers, IITA's training staff have developed a program of discussions and demonstrations with local farmers in their villages.

Alley farming research at a crossroads

AFNETA will soon begin to shift trials from research stations to small-scale farms and encourage farmers to experiment with and adapt technologies to meet their needs.

Research collaboration

The year's activities of ESARRN, SPALNA, and the IITA/Italy/USA/Belgium network for cowpea biotechnology research are briefly described. Two visiting scientists, Togolese maize breeder Mawule Esseh-Yovo and Italian biochemist Pasquale Petrilli, share their experience with IITA.

Leadership development through networking: the SAFGRAD example

As deserts expand in drought-prone Africa, news of success in agricultural development at the desert's fringe is welcome.

For the 26 sub-Saharan countries of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project, participation has enabled them to help create and diffuse new technologies for increased cowpea, maize, millet, and sorghum production. During the life of the project (1978–1992), their scientific establishments have been strengthened through training and improved communication with one another as well as with international centers.

The key strategy has been scientific networking, which has sustained their growth and will also benefit future research endeavors. The following pages describe how networking has supported scientific achievements and leadership development in SAFGRAD countries.

The SAFGRAD project was founded in 1977 under the auspices of the Scientific, Technical, and Research Commission of the Organization of African Unity (OAU/STRC), with principal funding by the United States Agency for International Development (USAID), to counter increasing drought in the Sahelian region. The main objective was to raise the productivity of the four staple food crops of that region (cowpea, maize, millet, and sorghum) to the extent possible, in order to reduce the impact of climatic irregularities on the food supply in that region and other semi-arid areas.

As an intermediary between the international research centers—principally, IITA and ICRISAT—and the national programs, SAFGRAD aimed to increase the effectiveness of national programs in interacting with international centers and performing adaptive research.

Small-scale family farmers benefit from improved technology for moize production

From 1978 to 1985 (phase I of the project) IITA initiated research and training activities oriented to the region, with a view to improve maize and cowpea varieties and develop cultural practices compatible with small-scale farming in the semi-arid tropics.

Results from that first phase produced technologies which were tested in regional trials by scientists from the national programs of the SAFGRAD member countries. Phase I demonstrated that regional commodity networks could help collaborating countries to develop and strengthen the capabilities of national scientists.

During SAFGRAD Phase II (1986–1991), direct agricultural research activities in Burkina Faso by IITA and ICRISAT were phased out and national research systems were strengthened. Problems of infrastructure have long militated against scientific communication in sub-Saharan countries—SAFGRAD's key role was to enable scientists in the region to communicate in diverse ways which would enhance the development of their research.

Three commodity-specific networks were organized, for research on maize, cowpea, and sorghum. IITA took responsibility for establishing the maize and cowpea networks in West and Central Africa and for providing coordinators and technical assistance for both networks. ICRISAT was responsible for sorghum.

Participating national programs and the international centers met to identify constraints on crop productivity and to agree on research priorities. Roles were assigned, based on countries' needs and available resources (human, equipment, and other facilities). Countries were designated as "lead", "associate", or "technology-adapting" programs, according to their capability.

The networks embarked on the following activities:

Monitoring tours. Teams of scientists from five to eight member countries made biennial tours to inspect field and lab trials in the region. The experience helped impart new ideas and stimulated interaction among the different programs. Between 1987 and 1992, two such monitoring tours were organized by each crop network.

Visits to national programs. In addition to the monitoring tours, networking scientists visited selected national programs annually. The objectives of the visits were (a) to assess the activities of the various national programs and help increase the effectiveness of their participation in the networks, (b) to assess the training needs, (c) to learn how maize and cowpea were utilized locally and, where necessary, advise on how to optimize production, and (d) to promote interaction between research institutions, development agencies, and small-scale farmers, for a realistic conception and implementation of research goals.

Through such visits, agricultural research and extension services in several countries have been restructured to facilitate the flow of appropriate technologies to farmers.

Joint workshops and seminars. The biennial workshops, seminars, and general conferences served as fora in which IITA and national scientists could report and discuss relevant unpublished findings in all aspects of research. Those meetings brought home to national scientists the challenges of sustainable improvement in agricultural productivity.

Researchers and technicians could exchange experience, while young scientists could develop a sense of professionalism and confidence in communication. More than 2,500 researchers and technicians attended those meetings and about 500 publications, including annual reports originated with project activities.

Leadership through training. Each of the networks sought to strengthen national programs, especially the lead centers, so that they could direct research activities themselves in the future. In SAFGRAD's first phase, training activities were directed at technicians. Emphasis in the second phase was on improving the research capability of scientists through seminars.

A well-trained senior scientist can have a multiplier effect—he or she can increase the quantity and quality of his or her own research output and serve as a resource person in on-the-job training to scientific personnel in the country.

By 1992 a total of more than 30 scientists had been trained to MSc and PhD levels by the maize and cowpea networks. Most of those trained have become research leaders in their respective countries. Short-term training in various aspects of crop improvement, production, and farming systems was also provided to 400 national researchers and technicians in more than 22 countries. As a result, during the 1980s the number of researchers tripled in Burkina Faso and Ghana, while in Niger the number almost doubled.

Network accomplishments

The networks have used practical means for setting up constructive relations among national programs, cutting across the language barrier that has existed between anglophone and francophone countries. They have shown how research responsibilities can be shared among scientists in different countries, thus minimizing duplication. Through collaborative research activities, national scientists have improved their research skills, become a source of technology development, and helped spread those technologies to member countries.

The six lead centers of the maize network (in Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Nigeria, and Togo) have developed 10 early-maturing, drought-tolerant varieties, and 15 extra-early maize varieties. The identification of extra-early maize varieties has been an avenue for extending maize cultivation into new areas, especially to the relatively dry Sudanian areas where the short rainy season normally precludes its cultivation. Significant expansion in maize production has occurred in Burkina Faso, Cameroon, and Ghana.

Harvest of extra-early maize in Burkina Faso

Improved agronomic practices for farmers have also been developed for specific needs. "Tied ridges", whereby the furrows between the planted ridges are dammed or "tied" at intervals to capture rainwater runoff, and minimum tillage systems were among those technologies with the greatest significance for farmer productivity.

The maize network has developed research facilities to enhance screening for streak resistance in Togo and Ghana. Those two lead centers have a regional responsibility for the conversion of maize germplasm for streak resistance, through which much of the success with maize has been achieved in the region.

Similarly, the six lead centers of the West and Central Africa cowpea network (in Burkina Faso, Cameroon, Ghana, Niger, Nigeria, and Senegal) have developed more than 10 *Striga*-resistant cowpea cultivars, 6 drought-resistant cultivars, and, in collaboration with IITA, 7 aphid-resistant cultivars. More than 76 cowpea cultivars with good adaptation to various ecological zones were made available to national programs through the network.

Although the SAFGRAD project ended in March 1992, USAID, the donor agency, has agreed to continue supporting specific activities of the maize network in selected countries until 1995.

Because of new interest in leguminous crops for resource management, the activities of the cowpea network will be integrated with those of a network to be established for resource management research.

On-farm orientation to improve research and training skills

The aim of IITA group training courses is to strengthen the knowledge, attitudes, and skills of agricultural researchers. Technical training is not, however, all that researchers need to do their jobs back home. They must also be equipped to set research priorities in relation to the needs of farmers. And they must be able to share their new knowledge with their colleagues at home after training. IITA's training staff thus seek to provide technical research skills together with training and communication skills essential for researchers who want to improve the effectiveness of their work.

Key to achieving those goals in training courses is a program of discussions and demonstrations with farmers in their villages in the Ibadan area, where IITA is located. The field exposure gives these trainees practical experience in communicating with farmers in order to learn from them.

Participants in IITA training courses are mostly research scientists and technicians, with some extension specialists and educators, from sub-Saharan African countries. Many of the researchers who come to IITA for training have had little firsthand experience with farmers, which they need in order to improve their research planning. Interaction with farmers helps researchers to appreciate traditional practices and technologies, and the scope for new alternatives in meeting farmers' needs.

Good listeners

By the end of their course, these trainees should be convinced that effective agricultural research begins and ends with farmers, the ultimate beneficiaries of their work. The trainees should routinely ask themselves "What do I need to know from the farmers?" whenever they work on a solution to a farming problem. Researchers and extension specialists who have learned to listen to farmers are better equipped to produce useful solutions.

Course participants come from a variety of backgrounds: research, extension programs, agricultural science education—in public or nongovernmental institutions. They are IITA's partners in collaborative activities with national programs. They are among those responsible for their countries' agricultural policy and food production.

To achieve IITA's training objectives, the curricula are framed in the perspective of local farming systems. Also, since 1990, courses on research and technology transfer in crop production have incorporated communications modules which feature:

• informal interviews with farmers early in each course, to help in analysis of farmers' constraints and opportunities.

• formulation of technical messages to respond to farmers' problems, for use in a "farmers' field day" at the end of each course, during which researchers and farmers exchange feedback.

This cycle of going to farmers to listen and learn, followed by returning to demonstrate possible solutions, has been built into courses on root crops (cassava and yam), grain legumes (cowpea and soybean), and maize from 1990.

Training staff involve local agricultural extension staff in selecting the villages to be visited, and in planning and conducting some of the field activities. Extension agents provide a linkage with resources for followup support that may be needed. Care must be taken, however, in the interviews so that extension staff do not answer questions on behalf of the farmers; and that they do not inhibit farmers from speaking frankly about their constraints, which often include inadequate service from local extension programs. Extension agents have, on the whole, been open and supportive in IITA's field work with farmers.

First the basics

Before the trainees go to the field, staff of IITA and Nigerian institutes who have on-farm research experience introduce the field work with a presentation on informal surveys and interviewing techniques. They provide only general guidelines so that the participants may formulate their own approach to the field work. Staff encourage participants to learn from the experience itself and from each other's feedback.

Throughout the course, participants develop their communication and training skills along with research skills. They practice written, visual, and oral communication techniques. They prepare for the field day by composing leaflets, posters, and texts with technical messages for newsletter and radio dissemination. Training and editorial staff coach them in training methods, demonstration techniques, and technical writing.

Communication with farmers is the critical link in the process of developing research for technological improvements in agriculture. And once researchers learn to communicate with farmers, they can also communicate fruitfully with other researchers. At home, in their national programs, the trainees will need to share the advances in knowledge and practical applications with their colleagues. They should therefore see themselves as trainers, as well as researchers.

On farm

In the field, the trainees first meet the farmers and extension agents collectively, beginning in the village with an appropriate welcome, introductions, explanation of purpose, and expressions of appreciation. The company breaks into smaller groups and moves to individual farms for a full picture of the farming system.

Farmers show and tell the trainees about the conditions they work under every day. The extension agents may offer a few words about their own roles and experiences. The complex social and economic setting of the farm comes to life for the trainees, enabling them to revise preconceptions they may have about farmers and farming that do not correspond with reality.

During the interviews, the researchers must be alert to farmers' biases or risk invalidating the results of their survey. In an interview in one village during 1992, the farmers were asked how many of them lived there. Counting themselves and absent friends, the farmers replied there were 12. The interviewers asked if those 12 included any women—the reply came back that women were not considered to be farmers. Yet, as the training group spoke further with both men and women in the village, it became clear that women had been doing a considerable amount of farming. As the villagers' economic situation had worsened in recent times, moreover, women had been enlarging their farming roles. Getting the real picture is essential for researchers, particularly in this case if technologies will affect men and women farmers differently.

After the interviews, the training groups meet together in the village to pool what they have learned about the local farming systems and community. If gaps in information exist, they return to the farmers to ask further questions.

Back at IITA, the interview data provide the basis for work on solutions for farmers' problems. The results are pooled and the researchers form groups around problems with a common solution. By the end of the first week of the course, all the groups have prepared outlines of their proposals, which are vetted in a general discussion among participants and IITA staff scientists.

Proposed solutions may range over improved crop varieties, improved cultivation practices, rapid multiplication of planting materials, seed storage and preservation techniques, and new methods of crop utilization after harvesting. The participants develop their solutions over the rest of the training period, in tandem with other course work. They gather technical material from class presentations, library resources, and IITA scientists. The dual challenge of this exercise is to frame the technical solution in a message which can be effectively communicated to the farmers during a "farmers' field day" at the end of the course.

IITA trainees showing improved cassava "sticks" and planting methods during a farmers' field day

Before the field day arrives, the groups rehearse the event for each other and IITA staff. The presentation helps them to focus on their essential message and become familiar with the materials and equipment they will use. The rehearsal is videotaped, so participants can see themselves as their audience sees them and revise mistakes.

Farmers' field day

During the final week of the course, the trainees conduct a field day with the farmers they interviewed during their first week. Although the first village visit involves interviews with only 10 to 15 farmers, field days usually attract up to five times as many.

Each group stakes out its own area to present a possible solution to one of the farming constraints. About 10 to 12 farmers at a time see and discuss each demonstration. They practice the techniques and handle the materials themselves. Sample planting materials of improved varieties are often provided to them. Farmers share their reactions frankly with the researchers about shortcomings or strong points they perceive in the proposed technologies.

After their field day, the trainees assess what the experience has taught them. Although some of the researchers may at first have been sceptical about direct involvement with farmers, many observe afterward that their experiences with farmers have been among the most valuable of the course. Researchers thus acquire a new appreciation of their roles, in fostering a dialogue of problem-solving and feedback between the lab and the farm.

Impacts

IITA prizes its good relations with farming communities and extension agencies, so it takes pains not to create expectations that cannot be met. Often farmers complain that they do not have adequate access to improved technologies, basic inputs, and services. IITA training staff thus try to enlarge the training exercise into a means of strengthening linkages among researchers, extension agents, and farmers.

During 1992, one year after a field day, a followup visit to one community revealed that the brief intervention had indeed had positive results, because the technologies introduced at the time had really met farmers' needs. The farmers greeted the IITA returnees enthusiastically and warmly. They described how they had adopted some of the new practices and showed samples of the improved maize harvest from the previous year. They evidently valued the much larger cobs, which had begun to supplant the less productive local maize.

Multiplying the message

For the past 25 years, IITA has trained over 7,000 agricultural researchers and other technical specialists. During that time national research programs in sub-Saharan Africa have developed their human and capital resources—and increased their demand for further training.

IITA (as with other international centers) can no longer fulfill all of the training demand it attracts. Therefore, taking advantage of improved technical capabilities in several countries, IITA is beginning to devolve training in crop management research to national programs. IITA will increasingly devote its own training resources to specialized research programs for individuals and groups.

IITA is sharing its training methodology and experience with selected countries in each region, so that they can work with IITA in conducting training for themselves and other countries in their region. In this decentralized fashion, the message can be diffused farther and faster than ever: effective agricultural research begins and ends with farmers.

Alley farming research turns to the farmer

Alley farming is a way of making agriculture mimic the forest. The goal is to sustain the fertility of farmlands by approximating the self-sustainability of the forest ecosystem.

Selected tree species (usually nitrogen-fixing legumes) are planted in rows. In the "alleys" between those hedgerows, food crops are grown. Soil fertility is improved with nitrogen and other nutrients from prunings of the trees which are left on the ground to decompose. Prunings also supply forage for small livestock. The hedgerows provide the restorative processes of a fallow while the farm can produce food and fodder on a continuous basis.

On-farm testing of alley farming methodology has been developed over the past three years through international research coordinated by the Alley Farming Network for Tropical Africa (AFNETA). Reports from participating scientists in most AFNETA countries suggest that the research has reached a critical stage where the farmer must also have a hand in adapting the technologies to the exigencies of life on the farm. In beginning its next project phase, AFNETA has charted a new path of participatory research with farmers and development support agencies, to bring the goal of sustainable agriculture within reach.

The idea evolves

Alley farming research evolved during the 1970s at IITA, as a land use system for managing the fragile uplands in the humid and subhumid (forest and savanna) zones of sub-Saharan Africa. The aim was to develop a substitute for the traditional bush-fallow, slash-and-burn system of land renewal.

At first the emphasis was on crop production between hedgerows of leguminous trees or shrubs, in a system wherein cropping and fallow processes take place concurrently; hence, the term "alley cropping". The International Livestock Center for Africa (ILCA) enlarged the concept to include small ruminants (mostly goats and sheep) with the use of hedgerow foliage for forage. Known as "alley farming", this agroforestry system also supports farming through erosion control, moisture conservation, weed suppression, and production of firewood and staking material. Potentially, the system is "scale neutral"; that is, equally applicable on large- and small-scale farms—although most research to date has focused on smallholder systems.

Two divergent approaches to alley farming exist—alley farming as a "conservational" technology or a "restorative" technology.

- The conservational approach affirms the original tenets of the technology as a replacement for bush fallows, to prevent soil degradation in areas where the soil is still reasonably fertile and secondary or primary forest exists.
- The restorative approach has evolved more recently as a solution to the problem of rapid soil degradation under high cultivation pressure to support high-density populations.

The two purposes to be served by these approaches call for different types of alley farming applications. Both need to be investigated further and validated. Work on the restorative approach has proceeded much further than research on the conservational approach, however. Farmers are not easily persuaded to invest their efforts in sustainability projects in areas where forest lands remain unexploited and farmland is otherwise not in short supply.

After a decade of development, alley farming's main proponents (IITA, ILCA, and ICRAF) resolved in 1986 to deepen involvement of national agricultural research systems in the research. The three centers conceived of a networking apparatus for collaborative research which could combine the strengths of all concerned in a mutual development effort. After three years of organizational and fund-raising preparations, AFNETA was established in February 1989 with funding support chiefly from the Canadian International Development Agency (CIDA), the International Development Research Centre (IDRC, of Canada), and the International Fund for Agricultural Development (IFAD). The Danish International Development Agency (DANIDA) supported part of the network's takeoff activity. The United States Agency for International Development (USAID) has contributed support for some collaborative projects with US universities. The Ford Foundation and the Overseas Development Administration of the UK have supported training activities. With alley farming research and extension as its raison d'être, the network has also aimed to ensure the relevance of the technology for sustainable farming systems, and to enhance its adoptability for farmers.

AFNETA completed its first three years of continentwide activity in 1992. During this first phase some 32 national institutes in 22 countries helped generate a body of data and insights about hedgerow species and crop interactions, which forms the nucleus of a computer-based "expert system" of information being developed at the University of Hawaii for use by networking institutions. AFNETA participants conducted 95 projects in the principal agroecological zones. Their investigations were organized around a sequence of issues for development, as summarized in the accompanying table (at left).

Types of alley farming research projects by country and region of sub-Saharan Africa

Region/Country	Hedgerow	Management	Livestock	On-farm
Western				
Benin	3	2	3	1
Burkina Faso	2	2	0	0
Côte d'Ivoire	2	4	0	0
Ghana	2	2	0	1
Guinea	2	0	0	0
Liberia	1	0	0	0
Mali	2	1	0	0
Nigeria	0	4	0	3
Senegal	2	0	0	0
Sierra Leone	0	2	0	4
Togo	3	3	0	1
Central				
Cameroon	0	3	2	1
Zaire	1	2	0	0
Eastern				
Burundi	0	1	0	0
Ethiopia	3	3	0	0
Kenya	0	2	0	2
Rwanda	0	2	1	2
Uganda	1	2	0	2
Southern				
Malawi	1	3	0	0
Tanzania	0	4	0	1
Zambia	2	0	0	0
Zimbabwe	1	1	0	0
Total research projects	28	43	6	18

1. Screening and selection of multipurpose trees for hedgerows

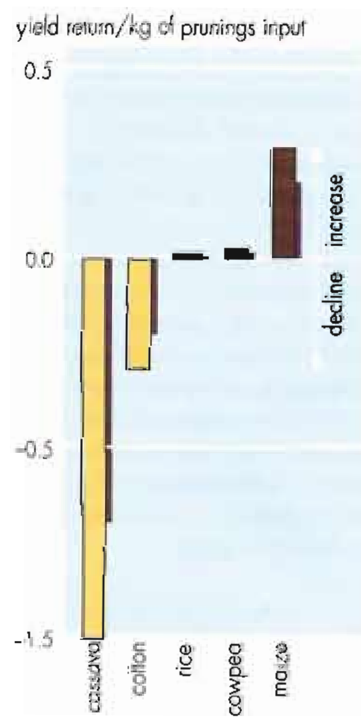
The essential qualities in selection of hedgerow species are capability for soil fertility improvement, ease in establishment adaptability to soil problems and other environmental stresses (such as drought, altitude), and usefulness of byproducts such as fuelwood, stakes, forage, and medicines. Establishment of hedgerows is the farmers' first hurdle, which must be crossed with the right choice of tree species for local soil and other conditions.

Agroecological considerations determined the species for screening at each site. Some species performed well in specific zones. But three species in particular showed wide adaptability across the various zones, the best growth in semiarid sites, and superior growth in subhumid (savanna) sites: two *Cassia* species (*C. siamea* and *C. spectabilis*) and an *Acacia* (*A. auriculiformis*). Tree establishment was problematic in on-farm trials, especially in the humid zone. The data collected to date on tree performance and durability are, however, preliminary and will need to be substantiated over the next few years. A particular issue for investigation is the nitrogen budget of the *Cassia* species, in view of their high nitrogen productivity and all-around successful performance, vis-a-vis their inability to fix atmospheric nitrogen in the soil.

2. Alley farming management

Proper management, with the right choice of hedgerow tree, is expected to deliver the promise of alley farming: maintenance of soil fertility, together with high yields of food crops. The farm manager must decide what the tradeoff is to be, in allocation of hedgerow foliage for mulching material or fodder. In assessing research results, problems arising from purely biological aspects—such as above- and below-ground competition between trees and food crops—must be separated from problems amenable to management.

Return in crop yields from hedgerow pruning inputs on alley farm projects in sub-Saharan Africa



SOURCE
AFNETA Phase I Report (1989-1992). IITA, Ibadan. 15 June 1992

Alley farm under farmer management

Interactions between hedgerow trees and companion food crops have shown startling yet consistent differences for specific crops. The accompanying chart (opposite) shows preliminary results from continuing trials with cassava (10 cases) and cotton (4) produced lower crop yields on alley farm plots than on no-tree control plots. Results with cereals (44 cases of maize, 6 of rice) and grain legumes (9 of cowpea) were consistently higher on alley plots than on the no-tree plots.

Most of the cassava results came from the humid forest zone, while those of maize came mainly from the moist savanna and savanna/forest transition zones. Other crops will have to be tested on alley farms in those same zones, to enable AFNETA to determine whether the technology as a whole is suitable for each particular zone.

3. Livestock integration

Forage crops should be part of the total intercropping scheme on alley farms with a livestock component. Forage research encompasses (a) production of the tree forage and pasture crops between the hedgerows; and (b) the fodder value of forage crops in terms of digestibility, protein content, and effects on livestock productivity. Trials of only type (a) were conducted during the first phase of AFNETA.

Preliminary results yield a sketchy picture. In the Republic of Benin, slow-growing pasture grasses seemed to be more compatible with the hedgerows than were vigorously growing grasses, which needed to be cut frequently during the first year so that the hedgerows could establish well. Cameroon trials encountered similar establishment problems, but grasses in the alley plots had a higher protein content and were greener than those in no-tree control plots.

4. On-farm research experience

On-farm research is essential in fine-tuning the technologies, assessing their productivity under farmer management, and determining their potential adoptability and farmers' interest in them. Two types of on-farm trials were conducted:

- experimental, which help in validating technologies or testing their performance.
- developmental, which involve systematic introduction of technologies into a farming community and assessment of their acceptability to the farmers.

The results from the range of experimental and developmental sites during 1992 on the whole have indicated that AFNETA on-farm research methodology needs to be further developed during the next phase of the network's program. Experimental trials on farms in Rwandan savanna lands demonstrated clearly superior crop production under alley cropping systems than in no-tree control plots. Developmental trials have yielded diagnostic information on farming constraints and potential acceptability of alley farming solutions, and have introduced some solutions for farmers to test and adapt.

Making the idea sell

The concerns of developmental research characterize plans for AFNETA's next three years. In building on the results of the first project phase, the research agenda for AFNETA's second phase (1994–1999) calls for a new direction in strategy. Ways must be found to encourage farmers to experiment with and freely adapt alley farming to meet their needs. To date, few of the farmers who have been introduced to the idea have adopted it, although on-station research has yielded highly favorable results.

The new strategy will involve farmers as "co-researchers" together with local public or private development agencies as co-promoters. Such a participatory approach to the research should open the way for AFNETA to tackle the chief developmental concern of "adoptability" of alley farming.

The approach should lead to answers to the following questions:

- *How workable is the idea under farm conditions?* The positive results from research station experience over many years are difficult to reproduce on working farms under farmer management.
- *Does the system address the farmer's own perceived problems?* Researchers need to examine whether their agenda to date has been reflecting correct assumptions.
- *What research approaches will encourage farmers to start making their own adaptations, and thus promote adoptability of the system?* The participatory approach is seen as a key way to unlocking solutions to the current impasse.

AFNETA researchers will strengthen farm-level development and extension activities, which are essential in adapting and disseminating new technologies. Farmers and promoter agencies will join AFNETA in designing research options, adapting experimental technologies, and evaluating the results.

Experiments will shift from research stations, where most of them are currently located, to small-scale farms where the farmers can participate to the fullest extent that they can. The new farm-oriented research and development strategy should help to produce results which farmers will want to adopt for their demonstrated capability to sustain farm productivity.

AFNETA seeks to test whether alley farming is more than just an ecological pipe dream—whether it can provide realistic and practical options for overcoming problems of soil degradation, thereby creating a sustainable basis for tropical agriculture. During the next few years, AFNETA's research activity will become a process of operationalizing alley farm technologies, profitting from the synergy of scientists, farmers, and development agencies.

Research collaboration

EAST AND SOUTHERN AFRICA ROOT CROPS RESEARCH NETWORK

New horizons

After nearly a decade of research networking, since 1984, ESARRN is planning to divide into eastern and southern sister networks: the East African Root Crops Research Network (EARRNET) and the Southern African Root Crops Research Network (SARRNET).

EARRNET will be based in Kampala and focus on the needs of Burundi, Kenya, Madagascar, Rwanda, and host country Uganda. Retaining the Malawi headquarters, SARRNET will concentrate on 10 countries of the Southern African Development Community (SADC): Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, and Zimbabwe.

The United States Agency for International Development (USAID) and the International Development Research Centre (IDRC) will continue to provide the principal funding for the participating national programs during this new phase of project activity.

Root crops rescue

The devastating drought of the 1991–92 cropping season in Malawi prompted the government to encourage farmers to plant cassava and sweet potato, staple food crops that withstand drought better than cereals. The National Root Crops Multiplication and Distribution System (NRMDS) was set up to propagate varieties of both crops.

ESARRN has helped in planting improved materials and in managing on-farm multiplication. CIP has been providing technical assistance for sweet potato. FAO donated a truck to transport improved varieties to primary multiplication sites, at government research stations in the various regions, and secondary sites on farmers' fields. The primary support for this massive effort has come from USAID's Office of Foreign Disaster Assistance.

Cassava multiplicatian plots will yield planting materials in 1993

As a result of the campaign, over 1 million sweet potato slips have been distributed to farmers for planting and about 45 hectares have been planted to cassava for multiplication purposes. Planting material from this hectarage will be released to farmers during 1993. ESARRN has organized training in nursery establishment and management for extension personnel, to facilitate dissemination of the new planting materials. Farmers' field days have been organized for extension agents and their clients, where improved varieties have been exhibited and farmers have availed themselves of sample materials.

Farmers have been able to benefit quickly from the campaign, because ESARRN had set up an on-farm testing and distribution system during the preceding three years. Nongovernmental agencies, such as religious missions, World Vision, and Save the Children Fund, are directly involved with nursery establishment and distribution activities, which has also helped ensure farmer awareness and participation.

IITA outreach scientists estimate that about one-third of the country's farmers have adopted at least one of the three improved cassava and sweet potato varieties being disseminated. Currently, about two-thirds of farmers are making requests for cassava and/or sweet potato planting material through their extension agents. By contrast, only 3% had adopted one variety of sweet potato in 1991.

Today cassava is considered the country's second most important food crop for research purposes, after maize, according to Malawi's agricultural policymakers.

SOIL AND PLANT ANALYTICAL LABORATORIES NETWORK OF AFRICA

Fostering a maintenance culture

SPALNA organized a two-week training course in equipment maintenance, during October 1992, with the assistance of the University of Nigeria at Nsukka and IITA. Some 15 laboratory technologists participated in the course at Nsukka, coming from Cameroon, Ethiopia, Ghana, Niger, Nigeria, Tanzania, and Zimbabwe. Resource persons came from the universities of Guelph (Canada), Ibadan (Nigeria), and Louvain (Belgium) and from Pulse Instrumentation Ltd. in Canada.

Funding support for the course came from the Belgian Administration for Development Cooperation (AGCD), which also supports the network on a regular basis. French governmental project funds supported seven of the participants.

The SPALNA course sought to foster a "maintenance culture" among participants and network members. Maintenance culture translates into an attitude of care toward equipment, born of the conviction that prevention makes easier work than repair.

Laboratory managers have recognized that lack of a maintenance culture is a major problem with those laboratories in Africa which function poorly. With the regional economy undergoing stressful times, expensive equipment is more difficult to replace than ever. Moreover, few maintenance and supply services exist in Africa which can be conveniently called in.

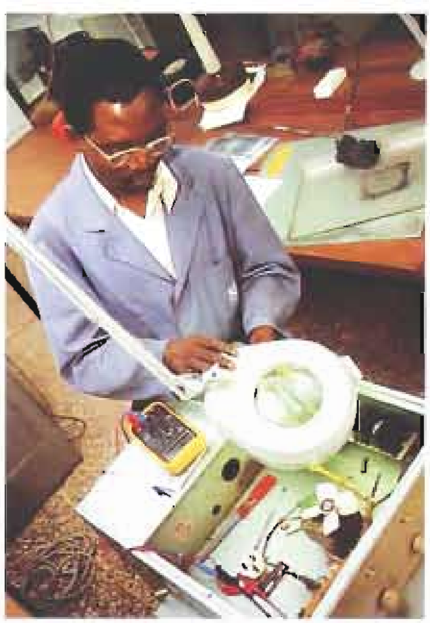
Laboratory technologists must be able to take care of the equipment under their control. The only way technologists can keep pace with current developments in laboratory equipment and procedures is through "self-education."

While not designed to make engineers out of the technologists, the training course gave them some troubleshooting experience in the identification of faulty parts and the replacement of simple components on such instruments as the pH meter. The course organizers had made arrangements with the Department of Customs and Excise to allow participants to bring their faulty equipment through, so that practical demonstrations in servicing and repair could be carried out. Each participant was presented with a comprehensive tool kit, with which repairs were carried out on the equipment.

The spectrophotometer (colorimeter) is an important instrument in the soil laboratory used in determining the concentration of phosphorous and the cyanide content in cassava, among other tasks. One Nigerian participant had brought a faulty spectrophotometer which served in demonstrating that repairs need not always be expensive. Upon examination, it was discovered that only the photocells were weak. When new photocells were fixed, the instrument, which had been discarded, could again be used.

Another spectrophotometer was found to have a damaged mirror, probably because of mishandling. The mirror was replaced with an inexpensive spare, giving new life to a discarded instrument. Sometimes it is a simple matter of changing a fuse in order to put an instrument back in working order.

The culture of care



The participants turned trainers during part of the course, giving a one-hour practical on equipment maintenance to six technologists from the University of Nigeria at Nsukka. That experience was intended to prepare participants to organize training for other laboratory technologists back home. Indeed, on returning home, the Zimbabwean participant organized in-country training to pass on his newly acquired knowledge to his colleagues.

IITA/ITALY/USA/BELGIUM COWPEA BIOTECHNOLOGY

Cowpea creativity: a mid-1992 progress report

The collaborative network for cowpea biotechnology gained a new partner during 1992: the Genetics Laboratory of the University of Ghent, Belgium (*Rijksuniversiteit Gent, Laboratorium voor Genetica*).

The networking institutes held their annual meeting, the Joint Cowpea Biotechnology Workshop, at the Germplasm Institute of the National Research Council at Bari, in southern Italy, from 29 June to 1 July 1992. From the USA, nine participants came from Purdue University and the University of Minnesota. Three participants came from IITA in Nigeria and one from the Genetics Laboratory at Ghent. From Italy came a total of 23 participants from the Germplasm Institute, the University of Naples, the Institute of Nutrition Studies, the Research Center on Vegetables for Processing, the University of Bari, the Institute of Agronomy and Vegetable Crops, and the Experiment Station for Cereals.

Purdue's Larry Murdock summarized the accomplishments of the IITA/USA/Italy collaboration to date, in a presentation entitled "Bright vistas, stumbling stones". He expressed his confidence that their mutual goal of genetically improved cowpea was in sight, and enumerated the milestones reached as follows.

1. Identified numerous wild *Vigna* species with resistance to post-flowering pests of cowpea.
2. Made an interspecific hybrid between *V. oblongifolia* and *V. luteola* that may serve as a bridge to bring

insect resistance genes into cultivated cowpea. [Also, developed in-vitro ovary culture and embryo culture methods, that can be used in producing plants from materials obtained from interspecific hybridization and harvested as early as one day after pollination—*Ed.*]
3. Improved our understanding of the cellular and cytogenetic basis of incompatibility between cowpea and *V. vexillata*, the latter a potential donor of insect resistance genes to cowpea.
4. Approached closer to understanding the basis of resistance of the variety TVu 2027 (and its derivatives) to cowpea weevil.
5. Understood better the nature and importance of anti-nutritional factors in *Vigna* species as well as learned more about the chemistry and physical properties of cowpea related to its role as food.
6. Developed expertise with physical and molecular techniques for the genetic transformation of cowpea cells, including the use of *Agrobacterium tumefaciens*, accelerated microparticles (the "gun"), as well as carried out trials with other techniques such as electroporation. Chimeric cowpea plants carrying foreign genes have been produced at Portici and Purdue.
7. Developed techniques for using the Purdue Insect Feeding Monitor to characterize cowpea weevil resistance. Worked out protocols for rapid screening of cowpea seeds for insect resistance. They are all available for transfer to IITA.
8. Attained new insights into the phylogenetic relationships among the *Vigna*, using protein profiles and RFLP techniques.
9. Increased quality and quantity of wild and cultivated *Vigna* germplasm available; described and characterized those materials.
10. Developed novel techniques for rearing insects on plant callus tissues—finding, remarkably, that the cowpea podborer*Maruca testulalis* fairly thrives on maize callus and will even survive on tobacco callus. Recognized the value of callus in assessing gene performance against insects.
11. Identified several proteins with potential to help protect cowpeas against certain cowpea insect pests, including *Bacillus thuringiensis* crystal proteins, α-amylase inhibitors, lectins and protease inhibitors.
12. Had in hand genes for (a) α-amylase inhibitor (α-AI) for common beans, (b) wheat germ agglutinin (WGA), and (c) several *Bacillus thuringiensis* crystal proteins. All of those genes are freely available to developing nations, with no strings attached, for use in cowpea transformation.
13. Had in prospect additional genes to use for this purpose, including a commitment from Monsanto Corporation to make available to Purdue their highly active modified *B.thuringiensis* gene for testing against cowpea insects. The results are promising—this gene might become available to developing countries through IITA.
14. Created vector constructs containing (a) α-AI and (b) WGA, useful for cowpea cell transformation using *Agrobacterium* and the "gun". Acquired seed-specific promotors that can serve to express genes in cowpea seeds.
15. Developed methodologies for quickly identifying transformed plants.
16. Transformed and successfully expressed the α-AI gene from common bean in cowpea cells. The biologically active protein product of this gene accumulated to an impressive degree in cowpea callus.
17. Attained new insights into the importance of carefully selecting the cowpea genotype to be transformed. Clearly, the genotype chosen can make a great deal of difference in the effectiveness of certain resistance genes in providing plant protection.

Persistence

In Dr Murdock's words, despite the encouraging advances made to date, the "stable transformation of cowpea plants has eluded us thus far. Transformation can be attained, without any doubt, if we persist. It is only a matter of time and money and continued commitment on our part.

"As regards the funding invested in the research so far, I think it is accurate to say that our accomplishments have been attained using what, by biotechnology industry standards, is a very small investment indeed. Now, with the crisis in funding for international centers before us, there is increased competition for funding sources. The simple fact is that without additional funding to continue and even increase the robustness of our efforts in cowpea biotechnology, the future is, at best, littered with stones over which we may easily stumble.

"Further, with limited resources, it is more vital than ever that all those who wish to participate in this good work do so not as competitors but as colleagues. All of us who, for years now, have worked toward this goal, warmly welcome any newcomers. We shall gladly share the last details of our experience and our best ideas and materials. In return, we ask only for the same. Rather than duplicating our efforts and, in some cases repeating work we've already done, we hope that newcomers will take their place beside us and add their strength toward a truly international effort. This would be a most welcome addition indeed.

"The key words are communication, linkages, sharing, trust, coordination, and good will. In the end, we should keep in our mind's eye a vision of the poor farmers and consumers in developing nations whose lives will be a little better if we succeed."

VISITING SCIENTISTS

IITA shares its research facilities with national program scientists who use them, as visiting scientists for periods of up to a year, to enhance their work back home. The benefits flow two ways: the distinguished visitors contribute insights from their own experience to IITA work, providing an extra dimension to research accomplishments at IITA. The collaborative experience also lays a foundation for a more substantial partnership between their programs and IITA in future.

During 1992, IITA hosted several scientists from developing and developed countries. The work of two of them, Mawule Esseh-Yovo of Togo and Pasquale Petrilli of Italy, illustrates the value of the collaboration for all involved.

Mawule Esseh-Yovo

Mawule Esseh-Yovo joined IITA's maize improvement program in April 1992 for a year as visiting scientist, with a special interest in maize streak virus resistance.

Dr Esseh-Yovo is the maize program leader at Togo's Directorate of Agronomic Research. After graduating from Université du Bénin, Togo, he pursued a master's degree in Bulgaria and, in 1979, completed his PhD degree in Bulgaria in plant genetics.

On his return to Togo, Dr Esseh-Yovo headed the development of his country's maize breeding program, with particular concern for producer and consumer varietal preferences. He also worked on streak resistance in maize. All along, Dr. Esseh-Yovo has had good collaborative relations with IITA and CIMMYT.

At IITA, Dr Esseh-Yovo investigated local varieties of maize from Benin, Cameroon, Côte d'Ivoire, Mali, Mauritania, and Nigeria, for streak virus resistance. The aim is to improve them by combining high-yielding characteristics and desirable grain quality. Local varieties and IITA inbreds with streak resistance are being combined in topcross hybrids. Trials are scheduled to start during 1993.

Research on streak at IITA led Dr Esseh-Yovo to develop a new method for screening, whereby plants are inoculated with viruses in the screenhouse, before being transplanted in the fields. The new method halves the usual failure rate in infesting plants with viruliferous insects.

Dr Esseh-Yovo also modified the streak inoculation procedure for use in infesting maize plants with *Striga* in the screenhouse.

In the course of his research, Dr Esseh-Yovo has become convinced that farmers must be included in decisionmaking about breeding materials in the early stages, to ensure that final results will be acceptable to consumers and adopted by farmers. The market price of maize is so low that grain quality must be fully acceptable to consumers, or farmers cannot afford to grow it.

Pasquale Petrilli

Pasquale Petrilli joined IITA's biotechnology research unit as a visiting scientist in August 1992. Dr Petrilli, an assistant professor and protein chemist at the University of Naples, Italy, had earlier visited IITA from October to December 1991, and will remain for a full year.

During his present tenure, Dr Petrilli will set up instrumentation for applying protein chemistry techniques at the biotechnology research unit. He plans to introduce new applications in protein chemistry to colleagues at IITA, especially those involved in crop improvement and plant health management efforts. This work will support the selection of new materials with desirable characteristics, using molecular markers and other diagnostic probes.

Molecular markers are usually proteins (isozymes) or nucleic acids which are detectably different between individuals. At IITA, such markers are being used in determining relationships among species, and in confirming the identities of parents and their hybrids in the evolution of new cultivars. They are also used in the construction of genetic maps of crops. The resulting information will help in introducing desirable traits from wild relatives into crop species.

Dr Petrilli will work with IITA colleagues to identify proteins involved in crop resistance mechanisms, isolate known proteins and enzymes and characterize them.

To achieve those objectives, IITA has recently acquired and installed equipment for protein analysis. A system will be set up to separate proteins using different kinds of chromatographic supports, including gel filtration, ion-exchange, and affinity columns.

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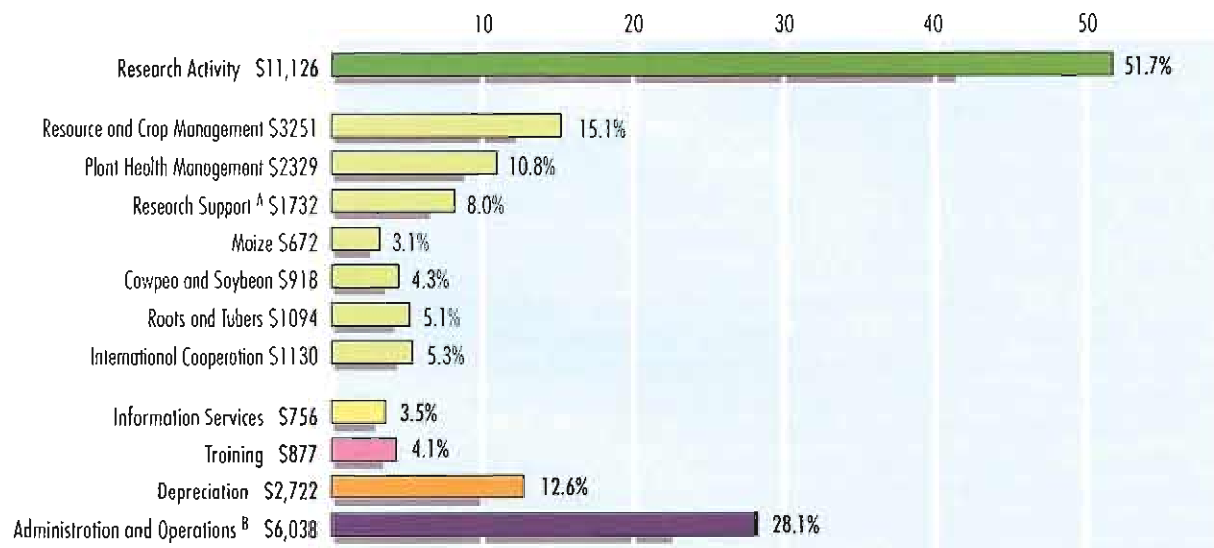
Major resource allocations Values in US $ thousands



[A] Includes Biometrics, Analytical Services, Genetic Resources, Research Farms, Biotechnology, and Agroecological Studies

B Net of overhead recoveries

Inventory of Research Projects

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Crop Improvement Division				
Root and Tuber Crops				
Cassava germplasm introduction, evaluation, and distribution	core, CIAT	CIAT, EMBRAPA, NARS	Colombia, Brazil, Nigeria	continuous
Cassava germplasm enhancement	core, DANIDA	NARS, ANU, RVAU	Australia, Denmark, Nigeria	continuous
International collaborative trials	core, NARS	NARS	var. sites, W & C Africa	continuous
National coordinated research trials on cassava	NSS, RRPMC	NRCRI	Nigeria	continuous
Yam germplasm evaluation and distribution	core	NARS	var. sites, W & C Africa	continuous
Yam germplasm enhancement	core	NRCRI	Nigeria	continuous
Postharvest technology	core	NARS, KU Leuven, ANU RVAU	Australia, Belgium, Denmark Nigeria	continuous
Utilization of cassava for baking bread	AGCD	KU Leuven	Belgium, Nigeria	1992–1995
Technologies for germplasm distribution of pathogen-free *Dioscorea* yams	ODA	Wye College	UK, Ghana, Nigeria	1992–1995
Maize				
Maize breeding for the savanna				
Yield potential	core	IAR, Pioneer	Nigeria	continuous
Striga resistance	core	NCRE/IRA, IAR	Cameroon, Nigeria	continuous

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

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Nitrogen use efficiency	core, GTZ	UI, Univ. of Hanover, IAR	Germany, Nigeria	continuous
Drought tolerance	core	SAFGRAD	Burkina Faso,	continuous
Grain quality and utilization	core, Guinness Nigeria Plc	IAR&T/IER, Hassan II	Mali, Nigeria, Morocco	continuous
Maize breeding for the forest				
Downy mildew resistance	core	IAR&T	Nigeria	continuous
Stem borer resistance	core	UI, CRI	Nigeria, Ghana	continuous
Husk cover and weevil resistance	core	Univ. of Benin	Benin	continuous
Grain quality and utilization	core, Guinness Nigeria Plc	IAR&T	Nigeria	continuous
Maize breeding for the midaltitudes				
Yield potential	core, UTC	UTC, NCRE/IRA	Nigeria, Cameroon	continuous
Disease resistance	core	UTC, NCRE/IRA	Nigeria, Cameroon	continuous
Germplasm enhancement				
Striga resistance in maize landraces	core	—	Nigeria	continuous
Characterization of maize germplasm by environments	core	SAFGRAD, CIMMYT	Nigeria, Burkina Faso, Côte d'Ivoire	continuous
Outreach				
SAFGRAD	USAID	SAFGRAD/OAU/USAID	Burkina Faso	continuous
International trials	core	NARS	Nigeria	continuous
Collaborative research with NARS	—	NARS	Nigeria	continuous
Plantain/Banana				
Plantain/banana breeding for durable host plant resistance	core/BADC	INIBAP, FHIA, CRBP, KU Leuven, NIHORT, CRI, IDEFOR, IRAZ, UNBRP and other NARS	Cameroon, Nigeria, Uganda	1987–
Developing *Musa* breeding capability and strategy	core	USDA/ARS, KU Leuven	Nigeria	1992–
Banana improvement for the midaltitude	core/USAID	NARS	Nigeria, Uganda	1992–
Biotechnology for *Musa* breeding	core	USDA/ARS, KU Leuven	Nigeria	1983–
Postharvest quality of plantains	core	NARS	Nigeria	1992–
Genotype-by-cropping systems interaction	core	—	Nigeria	1980–
Genetic Resources				
Cowpea protein identification/characterization	Italy	Univ. Naples	Italy	continuous
Interspecific hybridization of *Vigna* spp.	Italian universities, Italy	Purdue Univ.	Nigeria, USA	1989–
Grain Legumes				
Breeding for resistance to *Maruca* pod borer and pod sucking bugs in cowpea	core	UI	Nigeria	1989–
Cowpea varietal development for humid forest and Guinea savanna zones	core	—	var. sites, W & C Africa	1971–
Cowpea international trials	core	NARS, W & C Africa Latin America	Asia	continuous
Nationally coordinated research on cowpeas	Nigeria	IAR	Nigeria	1975–
Cowpea improvement for cereal-based systems of moist and dry savanna—improvement of local varieties: genotype x environment analysis: resistance to *Striga*, *Alectra*, *Maruca*, aphid, thrips, and bruchid	core	IAR&T, ABU, ICRISAT, TARC (Japan) VSO (UK)	var. sites, W & C Africa	1990–
Genetics of photosensitivity and phenological adaptation in cowpea	ODA	Univ. of Reading	Nigeria, Reading	1993–
Development of cowpea varieties for SADC region	EEC	SACCAR/SADC	E&S Africa	1990–
Soybean breeding for the savanna	core	—	var. sites, W & C Africa	1977–
Soybean international trials	core	—	var. sites, W & C Africa	1979–
Studies on promiscuous nodulation	NifTAL	NifTAL	var. sites, W & C Africa	1992–
Intercrop physiology of cowpea	core/IARC	TARC (Japan)	Nigeria	1990–
Development of cowpea and soybean for Ghana	CIDA	CRI	Ghana	1985–
Soybean processing and utilization	IDRC	IAR&T, UNN, NAERLS, NCRI	Nigeria	1987–
Biotechnology Research Unit				
Molecular methods for genetic mapping and detection of genetic diversity in *Vigna* spp.	Rockefeller Foundation	Univ. of Minnesota	Nigeria, USA	1990–92
Cowpea plant regeneration and genetic transformation	Italy, AUW	Purdue Univ., Italian universities	Italy, USA	Continuous
Monoclonal antibodies and diagnostics	IDRC	VRS	Canada, Nigeria	1990–92
Biotechnology for cowpea improvement	Belgium	Gent Univ.	Belgium	1992–95

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

Project title	Funding Sources	Cooperating Institutions	Location	Duration
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	UC	Benin, Nigeria	1982–92
Characterization of aspects of the biology and key interactions in the surrounding agroecosystem of *M. tanajoa*	core, UNDP	EMBRAPA, CIAT, Univ. of Amsterdam	Benin, Brazil, Cameroon, Colombia, Ghana, Netherlands, Nigeria, Rwanda, Sierra Leone, Uganda Zaire, Zambia	1983–95
Effects of farming practices on the biological control of the cassava mealybug	core	Univ. of Leiden, ETH	Benin, Ghana, Kenya, Malawi, Tanzania, Zambia	1988-
Epidemiology of African cassava mosaic virus	core, ODA	NRI	Nigeria	1992–94
Yam, Sweet Potato				
Biology and control of yam anthracnose	core	NRI	Nigeria	1992–93
Development and testing of sweet potato virus CDNA probes	IDRC	Agriculture Canada	Canada, Nigeria	1990–93
Maize				
Analysis of the maize ecosystem with focus on the most important lepidopterous pests of West Africa	core, GTZ	CABHIE, Simon Frazer Univ., Univ. of Reading	Benin, Côte d'Ivoire, Ghana, Malawi, Nigeria	1989–95
Studies on the biology of *Striga* spp. and their epidemiology; development of improved resistance screening techniques; improvement of resistance levels through the use of exotic germplasm; studies on the use of biological agents and agronomic practices for *Striga* control	core, GTZ	Old Dominion Univ., Univ. of Hohenheim, IAR, Univ. of Nsukka Tech. Univ. Braunsweig	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Nigeria, Togo, Germany	1989–95
Characterization of maize pathogens	core	—	Cameroon, Nigeria	1992–94
Epidemiology of maize streak virus and leafhoppers vector biology	core	Univ. of Illinois, NRI	Nigeria, Uganda	1989–94
Cowpea				
Feasibility study for the introduction of ecologically and economically sound pest management strategies adapted to subsistence farming systems	core, SDC	ETH, Univ. of Laval, ABU, ILCA, ICRISAT, Purdue Univ.	Benin, India, Nigeria	1987–95
Studies on virus diseases of cowpea	core	AUW, IRA	Cameroon, Mozambique, Nigeria	1990–93
Characterization of major pests and diseases in the Northern Guinea and Sudan savannas	core	IAR/Zaria	Nigeria	1991–94
Screening cowpea varieties for resistance to pathogens in the dry savanna	core	INRAN	Niger	1991–94
Soybean				
Studies on frogeye leaf spot disease	core	NCRI, EMBRAPA	Nigeria	1991–94
Biology of red leaf blotch	core	Univ. of Jos	Nigeria, Zambia	1991–93
Plantain/Banana				
Biology of *Mycosphaerella fijiensis*, causal agent of black sigatoka disease	core	—	Nigeria	1991–94
Screening plantain and cooking banana for resistance to black sigatoka	core	FHIA, INIBAP	Cameroon, Nigeria	1991–
Effects of ecological factors and agronomic practices on pest status of banana weevil and nematodes in highland bananas and plantain	Rockefeller, SDC	IIBC, CIAT, Agriculture Canada, Univ. of Laval	Benin, Nigeria, Uganda	1989–93
Postharvest studies				
Studies on postharvest insect pests of maize	core, ODA	UNB, NRI	Benin, Nigeria, UK	1989–94
Studies on postharvest insect pests of cowpea	core	Purdue Univ.	Nigeria, USA	1990–95
Ecological studies on the introduced larger grain borer in stored maize and cassava and in the surrounding habitats	IFAD, SDC, BMZ	INFAP, CP, CIMMYT EAP, Univ. of Göttingen	Benin, Honduras, Mexico	1988–95
Aspergillus flavus prevalence and toxicity pattern	WI, BMZ, WINROCK	Univ. of Berlin	Benin, Germany, USA	1992–95
Biological control				
MANGO MEALYBUG				
Biological control of the mango mealybug by the introduced parasitoid, *Gyranusoidea tebygi*: quantification of impact in different ecological conditions	SDC	Univ. of Leiden	Benin, Conakry, Côte d'Ivoire, Gabon, Ghana, Guinea, Nigeria, Sierra Leone, Zaire	1987–93

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

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Water hyacinth				
Rearing, release, and monitoring of *Neochetina eichhorniae*, a beetle feeding on water hyacinth	GTZ	CSIRO, IIBC	Benin	1991–93
Biorational control of acridid pests				
Neem oil as a possible alternative to insecticides used against locusts and grasshoppers	GTZ	Univ. of Giessen	Benin, Madagascar, Mali, Niger	1990–92
Joint biological control project against locusts and grasshoppers	USAID, CIDA, ODA, DGIS	DFPV, IIBC, Plant Protection Service of Benin, Niger, and Mali	Benin, Niger, Mali, UK	1990–93
Development of national biological control programs	GTZ, Austria, UNDP	NARS	25 sub-Saharan countries	1990–96
Faunistic and systematic studies				
Development of insect museum to support ecosystems analysis	Austria	IIBC	Benin, Cameroon, Nigeria	1991–93

Resource and Crop Management Division

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Resource Management				
Characterization of environments, resources and constraints				
Mapping of ecological and economic resource information and productive potential for West and Central Africa in a resource information system (RIS) and geographic information system (GIS)	AIDAB	ANU	W & C Africa	1990–
Characterization of resources and resource management in indigenous farming systems	—	NCRE, IRA, NCRI	Cameroon, Nigeria	1988–
Characterization and development of the Mbalmayo site	AIDAB	CSIRO, Obafemi Awolowo Univ., UI, National Herbarium, Cameroon	Cameroon	1991–
Adaptability and adoptability of alley cropping systems				
Adaptive capabilities of hedgerow trees	USAID	Univ. of Hawaii, Michigan State Univ.	Cameroon, Hawaii, Nigeria	1989–
Weed management in alley cropping	core	—	var. sites, W & C Africa	1989–
AFNETA research projects				
Multipurpose tree screening and evaluation (on-station)	USAID	ICRAF, Oregon State Univ.	Cameroon, Nigeria	1990–
Alley farming management trials (on-station)	IFAD/IDRC/CIDA	—	var. sites, W & C Africa	1990–
On-farm research with alley farming	IFAD/IDRC/CIDA	—	var. sites, W & C Africa	1990–
Multipurpose capability of herbaceous and shrub legume-based cropping systems	core	—	var. sites, W & C Africa	1989–
Development of agroforestry systems for the humid forest zone	core	ICRAF, IRA, NCRI, OAU	Nigeria, Cameroon	1989–
Determinants of sustainability in cropping systems				
Concepts and methods in sustainability research	core	—	Nigeria	1989–
Long-term sustainability of alley cropping systems	core	—	Nigeria	1989–
Comparative systems studies	GTZ	Univ. of Gottingen	Nigeria	1989–
Development of models and support systems for integrated management of tropical soils				
Integrated nutrient management for acid soils	core	—	Cameroon	1988–
Nutrient cycling in alley cropping systems	core	TSBF	Nigeria	continuous
Dynamics of soil organic matter	AGCD, DGIS	KU Leuven, ISF	Nigeria	1988–
Regeneration of degraded soils	core	—	Nigeria	1989–
Biology and control of *Imperata cylindrica*	core	—	Nigeria	1988–
Crop Management				
Humid forest systems				
Characterization and diagnosis of cassava-based systems	core, Univ. of Helsinki	Univ. of Helsinki	Nigeria	1989–1992
Collaborative study of cassava in Africa (COSCA)	core	Rockefeller Foundation, NARS	17 African countries	1986–
Strategic crop management studies	core	UI	Nigeria	1989–1992
Adaptability and adoptability of alley cropping	core, Ford Foundation	UI, NIFOR, EEC	Nigeria	1986–
Development of improved technologies for cassava-based systems	core	EEC	var. sites, W & C Africa	continuous
On-farm validation and impact of improved technologies	—	NARS	var. sites, W & C Africa	continuous

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

Project title	Funding Sources	Cooperating Institutions	Location	Duration
Savanna systems				
Characterization and diagnosis of savanna systems	core	NARS in 17 countries	sub-Saharan Africa	continuous
Development of improved technologies for maize-based systems	core	IAR	Nigeria	continuous
Impact of improved technologies	core	DRA, CRI	Benin, Ghana	continuous
Integration of legume-based technologies into farming systems	core	Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Zaire	Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria, Zaire	continuous
Impact of evolving production systems on *Striga*	core	IAR, NAES, IRA, (North), PASCON/FAO	Cameroon, Ghana, Nigeria	continuous
Determinants and consequences of intensification	core	IAR, NAES	Ghana, Nigeria	continuous
Inland valley systems				
Characterization and diagnosis of inland valley swamp systems	DGIS, core	Univ. of Gembloux, WARDA, NARS	var. sites, W & C Africa	1990–
Mapping of ecological and economic resources information	DGIS	Winanal Staring Centre	var. sites, W & C Africa	1990–
Strategic crop management studies	core	AUW, IIMI, ILCA	var. sites, W & C Africa	1990–

International Cooperation Division

Project title	Funding Sources	Cooperating Institutions	Location	Duration
NCRE Development of institutional capacity for research on cereals and facilities for transmitting research results to farmers	USAID	IRA	Cameroon	(Phase II) 1986–94
GGDP Development of varieties for major environments of Ghana	CIDA	CRI	Ghana	(Phase III) 1990–95
Ghana Smallholder Rehabilitation and Development Program Development of root and tuber crop production in Ghana	IFAD	CRI	Ghana	1988–92
SAFGRAD Development of improved varieties of maize and cowpeas and improved cultural practices with farmers in semi-arid regions	USAID	17 Sahelian countries	Burkina Faso	(Phase II) 1986–93
SADC Cowpea Research Project Development of cowpea production in SADC countries	EEC	Angola, Botswana, Lesotho, Mozambique, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe	INIA, Mozambique	1990–93
ESARRN Development of improved cassava and sweet potato varieties for sustainable production in East and Southern Africa	USAID, IDRC	Angola, Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Namibia, Rwanda, Sudan, Tanzania, Uganda, Zimbabwe	Malawi	(Phase II) 1992–95
AFNETA Applications of alley farming as a basis for sustainable farming systems	CIDA, IDRC, DANIDA, USAID, IFAD	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Liberia, Malawi, Nigeria, Rwanda, Sierra Leone, Tanzania, Togo, Uganda, Zaire, Zambia	Nigeria	1989–94
On-farm adaptive research for cassava, yam, rice, maize, cowpeas and soybean in tropical Africa Support for wide multilocation testing, multiplication, and distribution of improved varieties	EEC	Benin, Burkina Faso, Cameroon, Chad, Congo, Côte d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Nigeria, Principe, São Tome, Senegal, Sierra Leone, Togo, Zaire	Nigeria	1990–93
Utilization of cassava flour in baking bread Improvement in existing technology for baking bread, using pure and partially substituted flour	AGCD	KU Leuven, RVAU	Nigeria	1992–94

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

Project title	Funding Sources	Cooperating Institutions	Location	Duration
RRPMC Strengthening of nars of West Africa to conduct adaptive research, and to promote increased regional collaboration with IARCS	France, CGIAR	Benin, Cameroon, Congo, Gabon, Guinea, Nigeria, Togo	Nigeria	1992–94
Postharvest Design, development and field testing of improved postharvest technologies for selected villages in Nigeria	Ford Foundation	—	Nigeria	1990–1992

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

List of Abbreviations and Acronyms

ABU Ahmadu Bello University (Nigeria)
ACMAD African Centre for Meterological Applications for Development (Niger)
AFNETA Alley Farming Network for Tropical Africa
AGCD Administration générale de la coopération au développement (Belgium)
AGRHYMET Centre régional de formation et d'application en agrométéorologie et hydrologie opérationelle (Niger)
AIDAB Australian International Development Bureau
ANU Australian National University
AUW Agricultural University, Wageningen
BADC Belgian Administration for Development Cooperation, Belgium
BMZ Bundesministerium für Zusammenarbeit (Germany)
CABI Commonwealth Agricultural Bureau International (UK)
CIAT Centro Internacional de Agricultura Tropical
CIDA Canadian International Development Agency
CILSS Comité permanent inter-Etats de lutte contre la sécheresse dans le Sahel (Mali)
CIMMYT Centro Internacional de Mejoramiento de Maiz y Trigo
CP Colegio de Postgraduados (Mexico)
CRBP Centre Régionale Bananiers et Plantains
CRI Crops Research Institute (Ghana)
CSIRO Commonwealth Scientific and Industrial Research Organization
DANIDA Danish International Development Agency
DFPV Département de formation en protection des végétaux (Bénin)
DGIS Directorate General for Development Cooperation (Netherlands)
EAP Escuela Agricola Panamericana (Honduras)
EEC European Economic Community
EMBRAPA Empressa Brasiliera de Pesquisa Agropecuaria
ESARRN East and Southern Africa Root Crops Research Network
ETH Eidgenössisch Technische Höchschule (Switzerland)
FAO Food and Agriculture Organization of the United Nations
FHIA Fundacion Hondurena de Investigacion Agricola (Honduras)
GGDP Ghana Grains Development Program
GTZ Gesellschaft für Technische Zusammenarbeit (Germany)
IAR Institute for Agricultural Research, Samaru (Nigeria)
IARCS International agricultural research centers
IAR&T Institute of Agricultural Research and Training (Nigeria)
ICIPE International Centre of Insect Physiology and Ecology
ICRAF International Center for Research in Agroforestry
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IDEFOR Institut des Forets (Côte d'Ivoire)
IDRC International Development Research Center
IER Institut d'économie rurale (Mali)
IFAD International Fund for Agricultural Development
IIBC International Institute of Biological Control (UK)
IIE International Institute of Entomology (UK)
IIMI International Irrigation Management Institute
ILCA International Livestock Center for Africa
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)
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)
KUL Katholieke Universiteit Leuven (Belgium)
RVAU Royal Veterinary and Agricultural University (Denmark)
NAERLS National Agricultural Extension and Research Liaison Service (Zaria)
NAES Nyankpala Agricultural Experiment Station (Ghana)
NARS National agricultural research systems (in Africa; various)
NCRE National Cereals Research and Extension Project (Cameroon)
NCRI National Cereals Research Institute (Nigeria)
NIFTAL Nitrogen Fixation in Tropical Agricultural Legumes
NIFOR Nigerian Insitute for Oil Palm Research and Training
NIHORT National Institute for Horticultural Research and Training (Nigeria)
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 Agency (UK)
ONADEF Office national du developpement des forêt
PASCON Pan-African *Striga* Control Network
RRPMC Regional Research Project on Maize and Cassava
SACCAR Southern Africa Center for Cooperation in Agricultural Research
SADC Southern Africa Development Community
SAFGRAD Semi-Arid Food Grains Research and Development Project
SDC Swiss Development Corporation
TARC Tropical Agricultural Research Center (Japan)
TSBF Tropical Soil Biology and Fertility Program
UC University of California
UI University of Ibadan
UNB Université nationale du Bénin
UNBRP Uganda National Banana Research Program
UNDP United Nations Development Programme
UNEP United Nations Environment Programme
USAID United States Agency for International Development
USDA/ARS United States Department of Agriculture/Agricultural Research Service
UTC United Trading Company (Nigeria)
VRS Vancouver Research Station
VSO Volunteer Service Organization
WARDA West Africa Rice Development Association
WI Winrock International
WMO World Meteorological Organization

IITA

Statement of Financial Position

31 December 1992

Expressed in US $ thousands

ASSETS	1992	1991
Cash and cash equivalents	12,469	10,196
Accounts receivable:		
Donors	6,893	6,968
Others	1,542	918
Inventories	1,041	1,107
Other assets	278	201
Total current assets	22,223	19,390
Property, plant and equipment	31,612	32,241
Total assets	53,835	51,631
LIABILITIES AND FUND BALANCES		
CURRENT LIABILITIES		
Accounts payable and other liabilities	5,788	6,533
Accrued salaries and benefits	3,475	2,947
Payments in advance—donors	5,485	3,578
	14,748	13,058
FUND BALANCES		
Capital invested in fixed assets	31,612	32,241
Capital fund	2,883	2,109
Operating fund	4,592	4,223
Total fund balances	39,087	38,573
Total liabilities and fund balances	53,835	51,631

IITA

Statement of Activity

31 December 1992

Expressed in US $ thousands

REVENUE	1992	1991
Grants	35,725	34,274
Investment income	271	306
	35,996	34,580
EXPENSES		
Research programs	22,979	21,072
Conferences and training	2,026	2,103
Information services	756	760
General administration	3,924	3,279
General operations	3,220	3,391
Depreciation	2,722	3,466
Total expenses	35,627	34,071
Excess of revenue over expenses	369	509

IITA

Statement of Cash Flows

31 December 1992

Expressed in US $ thousands

		1992	1991
CASH FLOWS FROM OPERATING ACTIVITIES			
Excess of revenues over expenses		369	509
ADJUSTMENTS TO RECONCILE NET CASH			
Provided by operating activities:			
Depreciation		2,722	3,466
Reclassification of capital fund account		400	-
Gain on disposal of assets		145	282
Decrease (increase) in assets:			
Accounts receivable—donors		75	894
Accounts receivable—others		(624)	(555)
Inventories		66	1,437
Other assets		(77)	8
Increase (decrease) in liabilities:			
Payments in advance—donors		1,907	(396)
Accounts payable and other liabilities		(745)	(1,106)
Accrued employee benefits		528	(124)
Total adjustments		4,397	3,906
Net cash provided by operating activities		4,766	4,415
Cash flow used in investment activities			
Acquisition of fixed assets		(2,493)	(2,863)
		2,273	1,552
Net increase in cash and cash equivalents			
Cash and cash equivalents:	End of year	12,469	10,196
	Beginning of year	10,196	8,644
Increase in year		2,273	1,552

IITA

Donors 1992

Expressed in US $ thousands

DONORS	Core Funding	Special Project Funding
Austria	90	1,161
Belgium	662	533
BMZ, Germany	1,095	870
Canada	1,635	161
China	10	–
Commission of the European Communities	259	1,362
Denmark	348	99
Food and Agriculture Organization	–	87
Ford Foundation	100	159
France	291	–
India	25	–
International Development Research Center	–	778
International Fund for Agricultural Development	–	613
Italy	612	474
Japan	3,057	–
Korea, Government of	50	–
Nigeria	25	13
Norway	761	0
Rockefeller Foundation	304	208
Sweden	350	–
Switzerland	907	109
Netherlands	824	1,353
United Kingdom	700	4
United Nations Development Program	12	20
United States Agency for International Development	5,800	5,793
University of Hohenheim	–	209
World Bank	3,700	1
Other contributions (ICRAF)	–	48
Closed and miscellaneous projects	-	53
Total	21,617	14,108

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M. N. Versteeg, PhD, leader, technology transfer unit

IITA Cameroon station (Mbalmayo)
S. L. Claassen, MSc, farm manager

International cooperation and training division
J. P. Eckebil, PhD, deputy director general

International cooperation
E. F. Degonus, BSc, project development coordinator
O. M. Ogunyinka, MSc, coordinator, monitoring and evaluation
A. P. Uriyo, PhD, project development coordinator

Training
H. Gasser, PhD, director
A. A. Adekunle, MSc, research training specialist
M. Ajayi, MSc, research training specialist
J. L. Gulley, PhD, group training coordinator
F. R. Obubo, MSc, research training specialist
C. Okafor, MBA, administrative manager
O. A. Osinubi, MSc, research training specialist
A. Oyetunde, MA, editor
R. Zachmann, PhD, materials specialist

Interpretation and translation
B. F. Sali, head, interpretation/translation
E. Molinero, head, interpretation/translation*
C. H. Dia, interpreter/translator
O. B. Hounvou, interpreter/translator
C. Lord, interpreter/translator
V. Pousse, translator
H. Songre, interpreter/translator

Cooperative programs

USAID/IITA national cereals research and extension (NCRE) project, Cameroon
E. A. Atayi, PhD, chief of party and agricultural economist
D. C. Baker, PhD, agricultural economist
N. Beninati, PhD, maize breeder*
R. J. Carsky, PhD, systems agronomist
J. Detongnon, PhD, grain legume specialist
H. C. Ezumah, PhD, farming systems agronomist
M. Kamuongo, PhD, agricultural economist
D. McHugh, MSc, socioeconomist*
M. Moussie, PhD, senior agricultural economist/TLU coordinator
A. O. Osiname, PhD, farming systems agronomist
J. A. Poku, PhD, agronomist
G. L. Servant, PhD, administrative officer
T. C. Stilwell, PhD, deputy chief of party
H. Talleyrand, PhD, cereal agronomist*
C. F. Yamoah, PhD, soil scientist/agroforester

Semi-arid food grains research and development (SAFGRAD) project, Burkina Faso
N. Muleba, PhD, agronomist, coordinator cowpea network
B. Badu Apraku, PhD, maize coordinator

USAID/IDRC/IITA east and southern root crops research network (ESARRN), Malawi
M. N. Alvarez, PhD, breeder, network coordinator
J. A. Otoo, PhD, agronomist*

CIDA/CIMMYT/IITA Ghana grain development project, Kumasi, Ghana
A. M. Hossain, PhD, breeder (legumes)
O.O. Okoli, PhD, breeder (root crops)*

EEC/IITA/SADC cowpea project
J. D. Naik, PhD, legume pathologist/team leader
R. Amable, PhD, cowpea agronomist
A. L. Doto, PhD, cowpea breeder

IRRI/INGER Africa
K. Alluri, PhD, IRRI liaison scientist and coordinator, INGER Africa

IITA liaison office, Cote d'Ivoire
J. M. Fajemisin, PhD, research liaison scientist

IITA liaison office, Brazzaville, Congo
J. Aboka-Whyte, PhD, research liaison scientist

IITA liaison office, Kumasi, Ghana
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* Left during the year (1 April 1992–31 March 1993)

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Cover photograph
Detail of mosaic mural outside the entrance to the IITA International House at Ibadan, which was created by Elise Johnston to mark IITA's 25th anniversary in 1992

"IITA" inset photographs

"I" (left) dot is cowpea, stem is yam
"I" (right) dot is soybean, stem is alley cropping plot with leucaena and cowpea
"T" is hybrid plantain
"A" is hybrid maize

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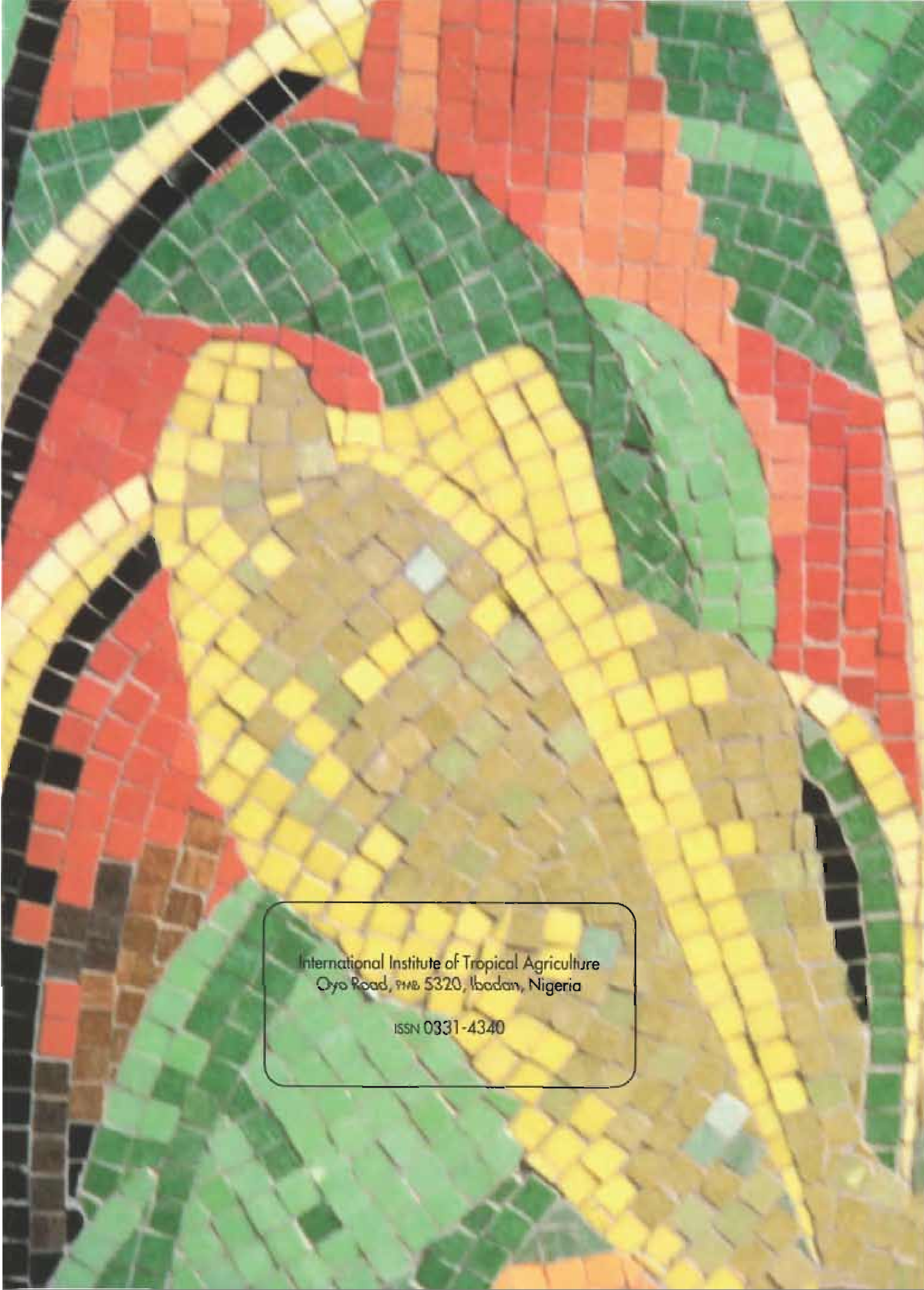

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