International Institute of Tropical Agriculture
ANNUAL REPORT 1991

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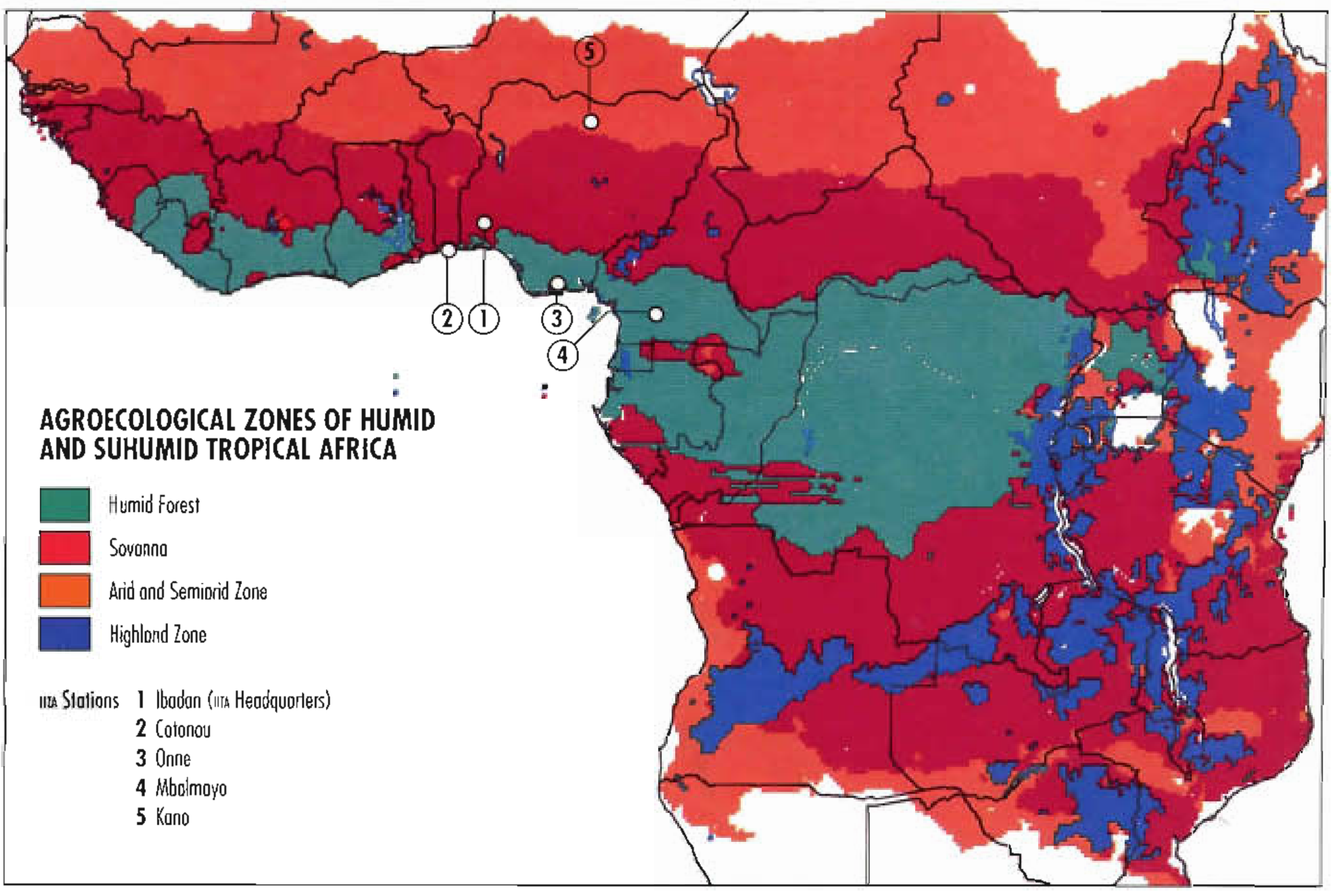
DIRECTOR GENERAL'S REPORT

On behalf of the Board of Trustees and the entire staff of IITA, I am pleased to present the Institute's annual report for 1991.

This reporting year includes the first half of the Institute's twenty-fifth year of existence, which began in July. The Nigerian government granted diplomatic privileges and immunities to IITA. The President of the Federal Republic of Nigeria, General I. B. Babangida, honored us with a visit during August. It was my first full year as director general. I consider it a great privilege to lead such a dynamic institute. The wide range of program activities and the results achieved during the year, which I would like to review for you briefly in these pages, are a rich source of satisfaction for all of us at IITA.

We are deeply concerned, however, that the reduction in financial resources among all the centers does not diminish the vigor of our endeavors. So far we have been able to continue strengthening our research activities by reducing overall management costs. Reduced resources have also stimulated new thinking about how best to accomplish our objectives. We started revising the medium-term plan, so carefully constructed for the



1989–1993 period, and decided to make it an opportunity for a team effort. We began with four Institute-wide meetings to discuss concepts on which to base the plan. The new plan will cover the years 1994–1998, and reflect a consensus of all scientists and managers.

In my observation this year, team effort has come to characterize more and more the scientific culture in the Institute, creating an environment in which scientists work together to produce their individual best. This team effort also embraces scientific colleagues in the various national programs—the results of their work, in the hands of the farmers, determine the usefulness of our mutual enterprise.

To strengthen team effort and encourage multidisciplinary approaches in our major research concerns, we modified our research management structure from the beginning of the year. One compelling reason is that multidisciplinary activity must be our means for applying an "eco-regional" focus in our work, in terms of the main agroecological zones. Also, sustainability research requires holistic thinking, in order to accommodate the complexity of interrelated problems in an effective framework for action.

research divisions established

We took a major step in establishing the Plant Health Management Division. Centered around the successful biological control program, it assembles all the Institute's plant protection scientists and reinforces a comprehensive approach to solving plant health problems. We combined the four crop programs into the Crop Improvement Division. Within the Resource and Crop Management Division, work continued along the lines of the three main agroecological zones in our mandate areas, in research groups for the humid forest, moist savanna, and inland valleys.

To ensure close interaction between research and management, the three division directors report directly to me. Together with the deputy director general for international cooperation, we form the research directors' committee which plans and monitors the direction of the Institute's research and training activities.

I take this opportunity to highlight our main achievements during the past year. You will find that many of these highlights are reflected in articles which follow in the body of this report.

Advances in crop improvement during 1991 include confirmation that our plantain-banana hybrids, resistant to black sigatoka, are ready for testing internationally, in different sub-Saharan agroecological zones, with the International Network for the Improvement of Banana and Plantain (INIBAP). National programs in Cameroon, Ghana, and Nigeria will collaborate with us initially. Our understanding of *Musa* genetics, acquired during the past two years, has enabled us to produce new varieties which combine high yields with resistance to black sigatoka and other production constraints—a unique achievement.

Our cassava scientists identified two aneuploids among progenies from polyploid cassava clones, the first in cassava ever to be cytologically confirmed. The aneuploids are cassava plants with eight and ten chromosomes—respectively—more than the natural complement of 36 chromosomes, which will influence the genetic variability in their progenies. They will be useful in analyzing the location of genes and manipulating them. We expanded our germplasm interchange with Centro Internacional de Agricultura Tropical (CIAT), specially emphasizing the introduction into Africa of germplasm adapted to the semi-arid and mid-altitude tropics. The program will benefit our collaborators in many African countries. Research on the process of cyanogenesis in cassava gained momentum during 1991 as two collaborating institutions joined us: the Australian National University and the Royal Veterinary and Agricultural University of Denmark. Together we are investigating environmental influences in differential cyanogenic potentials, and simple means to determine those potentials in the field. With the Catholic University at Leuven, Belgium, we developed a bread made of cassava, utilizing locally available

Lukas Brader, Director General of IITA.

ingredients including soybean flour, and produced a recipe book in a format for popular use.

In grain legumes breeding, the most dramatic news of the year came from one of our collaborators in the cowpea biotechnology network, the University of Naples. They have confirmed the first evidence of stable genetic transformation of the cowpea, using a marker gene from *Agrobacterium tumefaciens*. In soybean improvement, our research into cultural practices and resistance breeding for control of red blotch disease in West Africa should also benefit farmers in southern and central Africa, where the disease is endemic. Our soybean utilization research with Nigerian collaborators was strengthened, and preparations made to expand the project to Ghana.

Improved maize combining resistance to *Striga*, maize streak virus, and drought continued to show consistently good agronomic performance on site and on farm during 1991. A comprehensive breeding system for maize in mid-altitude regions proved to be effective in development of hybrids and open-pollinated varieties in Nigerian and Cameroon mid-altitudes. The latest open-pollinated variety showed yields, other agronomic traits, and disease resistance superior to those of any commercially available open-pollinated variety. The world's largest commercial seed company took the unusual step during 1991 of producing IITA's high-yielding and pest-resistant hybrid maize seed for their own market. They also began developing a hybrid cross between their own and IITA materials. In another commercial development which reflects on the advanced state of IITA's research, a second company used IITA hybrid materials for mid-altitude regions to produce their own seed stock for the Nigerian market.

Plant health research and assistance in program development extended to 35 countries across Africa during 1991. Our plant health scientists worked with national program colleagues in all aspects of plant protection against insects, mites, diseases, and weeds. Our approach is based on sustainable and ecologically sound methods, such as biological control, host plant resistance, and habitat management.

In biological control we collaborated in research, rearing, and release of natural enemies, follow-up surveys, institution-building, and training in 23 countries. We developed a four-year project on ecologically sustainable cassava plant protection, jointly with CIAT and programs in Brazil and four West and Central African countries. The first phase of a project on biological control of locusts and grasshoppers was successfully concluded, while preparations began for a second phase of expanded experiments and national program development. Our work on the larger grain borer, a pest of stored maize, expanded to include ecological research in Africa as well as the Americas, to aid our understanding of that pest/crop/environment system. Ecological research also continued in the maize system in respect of two other pests, the stem borer and the parasitic weed *Striga*, to help us develop further plant health interventions. Work to develop sustainable protection strategies for banana crops in East Africa got underway with a diagnostic survey.

On the particularly pressing problem of the parasitic weed *Striga*, over the past two years IITA has established the world's foremost *Striga* research facility. Our multidisciplinary group of 12 scientists is developing integrated packages for *Striga* control that can be introduced at farm level. Our research includes studies on host-parasite interactions, epidemiology and population dynamics, host plant resistance, biological control, habitat management, and the socioeconomics of implementing new control practices. The group conducts training programs at IITA and throughout Africa, and began last year to compile a *Striga* methodology handbook based on those programs.

Resource and crop management scientists continued to develop practical ways to operationalize and measure sustainability. They have proposed the use of a total factor productivity index which combines biological, physical, and economic factors to measure sustainability of a crop or a farming system.

> IITA's ultimate aim is "...to improve the nutritional status and well-being of low-income people..." in sub-Saharan Africa

Resource characterization of inland valleys in West and Central Africa was completed during 1991. Broad agroecological and economic zones were mapped at a scale of 1:5,000,000 and included the parameters of growing season, major soils, population density, and average capita income. In crop management research, IITA and the International Center for Research in Agroforestry (ICRAF) jointly conducted an ethno-botanical survey on multipurpose trees in Nigeria. About 285 species were identified as being useful in soil enrichment, as food or medicine, or for ornamental or other purposes. They were planted in arboreta at Onne and Ibadan for further study for use in agroforestry systems. Results of habitat management research of the noxious weed *Imperata cylindrica*, using the herbaceous cover crop *Mucuna pruriens*, were adopted in large-scale extension activities in the Republic of Benin. Over 2,000 farmers were reportedly testing the technology, while about 500 demonstration plots were established under the Global 2000 project in Benin.

Our collaborative study on cassava is providing data on the role of women farmers.

The training program conducted an internal review during 1991 of its strategy and activities, with the participation of colleagues from the research and management divisions, IITA trustees, and collaborators from several national institutions. The review endorsed the direction of the program and called for the pace of decentralization of group training to accelerate, toward in-country or national-level operations. During the year the program included 358 trainees in its various graduate research, non-degree, and group training activities, apart from those in regional and in-country training courses away from our Ibadan campus. By the end of the year, the program could count more than 7,000 alumni since training began in 1970.

In cooperation with the Cameroonian government, we established our new Humid Forest Station near Yaounde, the capital. Analytical laboratories were completed, adjacent to Cameroon's National Cereals Research and Extension (NCRE) project headquarters. The station's farm infrastructure was basically completed and began operating. The year also saw the beginning of the third phase of the NCRE project with support from IITA and the United States Agency for International Development (USAID). NCRE is a highly successful collaborative effort with 14 resident scientists working with national scientists. In parallel with the research agenda, testing and liaison units work with national extension agencies to transmit new technologies to farmers through on-farm testing, and to provide feedback on farm-level problems to researchers.

We decided during the year to place a research liaison scientist in each of three countries selected for their research capacity and impact potential: in Congo (for work in the humid forest zone), Côte d'Ivoire (for the moist savanna zone), and Ghana (for the forest-savanna transition zone). The research liaison scientists have a brief to link national activities having research and training needs with IITA programs and services, to develop effective solutions within a holistic perspective.

Early in the year we helped to launch the new Soil and Plant Analysis Laboratories Network for Africa (SPALNA), with more than 100 member laboratories in 30 African countries and a base at IITA. Our two collaborative groups in root crops research concerned with breeding and farming systems issues, respectively, joined forces during the year as the new Collaborative Group for Root and Tuber Improvement Systems (CORTIS), with member institutes from nine African countries. CORTIS began research with members of the Collaborative Group on Maize-based Systems Research (COMBS) on incorporating legumes into improved cropping systems, to maintain soil fertility and weed control. They prepared a database on legumes appropriate for different farming systems.

The Alley Farming Network for Tropical Africa (AFNETA) completed its third year with activities in about 20 countries. Research indicated that alley cropping is a good technology for sustaining maize-based production in the savanna zone. But suitable hedgerow species and cultural practices have yet to be developed for root-crop-based systems and the humid forest zone. The Collaborative Study of Cassava in Africa (COSCA) expanded from 6 to 14 countries during 1991, and its database is being used for analysis of many factors including the role of women farmers and impact of improved cassava varieties. For example, COSCA data show that IITA cassava varieties are widely adopted in Nigeria, where they are performing better than trial varieties; and that average cassava yield in Africa is now above 12 tons per hectare.

In connection with the programming of eco-regional research responsibilities among the international agricultural research centers, we began dialogues with ICRAF, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the International Livestock Center for Africa (ILCA) on cooperative research in overlapping eco-zones of mutual interest.

As the year drew to a close, preparations for the twenty-fifth anniversary celebrations during 1992 gained in tempo, with publications being compiled, posters designed for a retrospective of research results, and arrangements started for a symposium on sustainable food production in sub-Saharan Africa. Given the current economic situation, plans are being kept relatively sober. Our chief aim is to inform the public, through the medium of a year-long calendar of events with full staff participation, about IITA work and the ways we have translated our scientific vision into a farm-level reality.

With the range of research activities we have at IITA, we continuously need to redefine our collective mission. In that way we can sustain a relevant perspective on our impact in relation with the problems we are addressing. Especially considering the recent changes in our research environment, oriented toward intensifying cooperation with national programs and development of sustainable production systems, our board of trustees rearticulated our mission statement as follows:

IITA aims to improve the nutritional status and well-being of low-income people in the humid and subhumid zones of sub-Saharan Africa by carrying out research and related activities for increasing agricultural production in a sustainable manner, in cooperation with national and international systems and institutions.

Our goal of improving the lives of the poorest puts our scientific objectives into a perspective wherein the usefulness of our results can be measured. Our perspective must coincide with the national programs' views, to make for truly effective collaboration. The degree to which we work together with a shared vision determines how successful we will be in reaching the goal.

Lukas Brader

Many of our program activities are contributing to improved productivity for cassava farmers.

RESEARCH PERSPECTIVES

IITA AND THE CGIAR

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.

Funding for IITA research and operations comes from the CGIAR and bilaterally from 40 national and private donor agencies.

IITA is governed by an international board of trustees and is staffed by approximately 180 scientists and other professionals from about 40 countries, and 1,500 support staff. Most of the staff are located at the Ibadan campus, while others are at stations and work sites in other parts of Nigeria and in the countries of Benin, Burkina Faso, Cameroon, Ghana, Malawi, and Mozambique.

IITA conducts research, training, and germplasm and information exchange activities in partnership with regional and national programs in many parts of sub-Saharan Africa. Research is organized in three substantive divisions, for crop improvement, plant health management, and resource and crop management. A division for international cooperation conducts the training program and manages collaborative projects with national research programs. A division for management includes support services for finance, information, and general administration.

The research program focuses on six major food crops and smallholder cropping systems in the humid and subhumid tropics of Africa. These crops are:

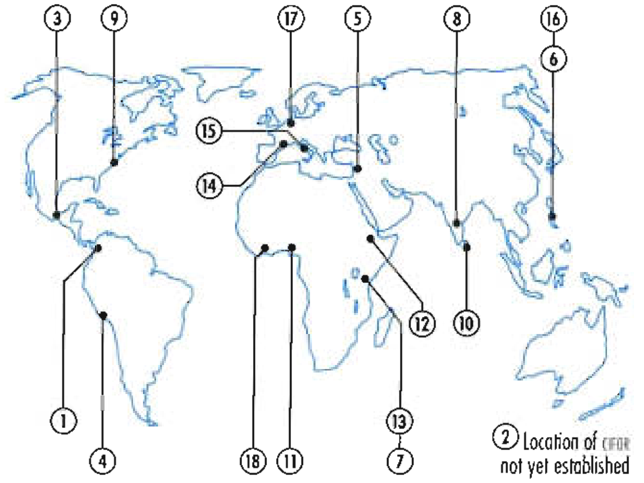
- cassava and yam—root crops which are staple foods for more than 200 million Africans
- plantain—a staple food for an estimated 70 million Africans
- maize—a major crop whose food and industrial uses in Africa are rapidly growing in importance
- cowpea and soybean—grain legumes which are important sources of protein for rural and urban Africans.

The research agenda addresses crop improvement, plant health, and resource and crop management issues within a farming systems framework. Goals of increased

IITA research farm and residential community at the Ibadan Headquarters.

Member centers of the CGIAR

1 CIAT Centro Internacional de Agricultura Tropical
2 CIFOR Center for International Forestry Research
3 CIMMYT Centro Internacional de Mejoramiento de Maiz y Trigo
4 CIP Centro Internacional de la Papa
5 ICARDA International Center for Agricultural Research in the Dry Areas
6 ICLARM International Center for Living Aquatic Resources Management
7 ICRAF International Center for Research in Agroforestry
8 ICRISAT International Crops Research Institute for the Semi-Arid Tropics
9 IFPRI International Food Policy Research Institute
10 IIMI International Irrigation Management Institute
11 IITA International Institute of Tropical Agriculture
12 ILCA International Livestock Center for Africa
13 ILRAD International Laboratory for Research on Animal Diseases
14 INIBAP International Network for the Improvement of Banana and Plantain
15 IPGRI International Plant Genetic Resources Institute
16 IRRI International Rice Research Institute
17 ISNAR International Service for National Agricultural Research
18 WARDA West Africa Rice Development Association



crop productivity and sustainable resource management are focused within the practical scope of small-scale farming systems in the following agroecological zones:

- humid forest (length of growing period 10–12 months)
- moist savanna (length of growing period 6–9 months)
- inland valleys (a distinct type of agroecosystem alongside drainage systems throughout continental Africa).

Following its 1989–2000 strategic plan, IITA has concentrated its research to date in West and Central Africa. Current plans are extending the agroecological approach on a region-wide scale, to cover the entire humid and subhumid zones of Africa. IITA has also begun to decentralize its research from Ibadan to representative locations in the various zones, where research on farming conditions and the crops is targeted.

In agroecological terms, the Ibadan site with 300 hectares of experimental fields provides conditions typical of the forest fringe and savanna transition zone. IITA has four other research stations in different zones.

In the coastal zone around Port Harcourt, Nigeria, IITA established its High Rainfall Station at Onne in 1976. Scientists at the 100-hectare site conduct research on plantain and banana crops, soil management, various cropping systems, and agroforestry applications.

In 1989 IITA established a 105-hectare station in the dry savanna zone at Kano in northern Nigeria, jointly with the Institute for Agricultural Research, Ahmadu Bello University. Cowpea cropping systems are the main focus of collaborative research with IAR and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

In 1990 IITA established its Humid Forest Station on 1,000 hectares at Mbalmayo, near Yaounde, the capital of Cameroon, in collaboration with the National Cereals Research and Extension Project. IITA and Cameroonian scientists there are developing technologies for sustainable small-scale farming in the lowland humid forest zone of tropical Africa.

IITA also established a center for Africa-wide biological control research and operations at Cotonou, capital of the Republic of Benin, in 1988.

Global links. The CGIAR is an informal association of about 40 governments, international organizations, and private foundations. During 1991 they provided about US$232 million in core funding. The CGIAR supports 18 international research centers, whose collective goal is to improve the quantity and quality of food production in developing countries.

The CGIAR states its mission to be: "Through international research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture, forestry, and fisheries in developing countries in ways that enhance nutrition and well-being, especially among low-income people."

Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP), the CGIAR operates without a formal charter, relying on a consensus derived from a sense of common purpose.

Each CGIAR-affiliated center is independent and autonomous,with its own structure, mandate, and objectives, and is overseen by its own board of trustees. Some centers focus on one or two food crops for which they have global mandates, while others have regional or ecological mandates for one or more crops. Still others perform specialized functions in such fields as food policy, plant genetic resources, agroforestry, irrigation management, and national agricultural research management in developing countries.

The CGIAR is serviced by an executive secretariat, which is provided by the World Bank and located in Washington. The CGIAR's Technical Advisory Committee (TAC) of scientists is drawn equally from developed and developing countries. TAC makes recommendations on research programs and priorities, and monitors performance through annual program and budget reviews and periodic external reviews. TAC is supported by a secretariat provided by the three cosponsors of CGIAR and located at the headquarters of FAO in Rome.

The CGIAR meets twice a year, once in Washington in October or November, and once elsewhere in May. The meetings review program activities undertaken by the centers, discuss agricultural research needs, and adopt strategies to address those needs, as well as review proposals on funding and management issues.

CROP IMPROVEMENT

The Crop Improvement Division aims to conserve genetic resources and increase quantity and stability of production of IITA's mandated food crops. The Division works with national programs in sub-Saharan African countries to develop germplasm that is well-adapted to agroecological conditions, resists pests and environmental stresses, and suits farmers' and consumers' needs.

RESEARCH DIRECTIONS

Cassava and yam

- Breeding of new germplasm to continue, for adaptation to agroecological conditions in the humid forest, moist savanna, and mid-altitudes zones.
- Exploitation of exotic cassava breeding materials from specific agroecological areas in Latin America and Africa to continue.
- Resistance levels to cassava mealybug and cassava green mite to be increased, as part of a plant health management strategy.
- Research will continue on cassava physiology and methods of selection for resistance to drought and cold.
- Research to continue on the inheritance, biochemistry, and physiology of food quality characteristics, including low cyanide content, and on the stress reactions of the plant.
- Cytogenetic and biotechnological techniques to be applied in characterizing genotypes, elucidating phylogenetic relationships, and improving efficiency in selecting desirable characters for new genotypes.
- Basic research to continue, jointly with advanced laboratories, on somatic embryogenesis, somatic hybridization, anther and pollen culture, and genetic transformation and regeneration, in order to improve efficiency of breeding techniques.
- Investigation of the physiological and reproductive biology of yam, and manipulation of ploidy levels in cassava and yam, to continue.

Plantain/banana

- Investigations of breeding strategies and methodologies for African conditions and constraints to be continued.
- Crosses between starchy bananas (triploids) and diploids to be continued, to provide more hybrid seed for clonal production, evaluation, and selection in East Africa.
- Development of a molecular linkage map to begin, in collaboration with the US Department of Agriculture in Griffin, Georgia, for germplasm management, gene mapping, marker-assisted selection for breeding, and management of in vitro germplasm conservation.
- Advanced multilocational trials of black-sigatoka-resistant plantain/banana hybrids to continue, in cooperation with national programs in 10 West and Central African locations.
- Survey to assess consumer acceptability of fruit quality of black-sigatoka-resistant plantain hybrids. Quality parameters to be studied and defined.

Maize

- Improvement in host plant resistance to *Striga* species to continue.
- Germplasm to be sought with greater root vigor, to increase recovery of soil nitrogen.
- Breeding of resistance to two stem borers, *Sesamia* and *Eldana*, and to the grain weevil *Sitophilus*, to continue.
- Development of heterotic base populations, and integration of open-pollinated and hybrid breeding into a "comprehensive breeding system", to continue.
- "Maintenance breeding" of agroecologically adapted germplasm to continue, in order to maintain resistance to maize streak virus, rusts, blights, downy mildew, and ear and stalk rots.
- Studies to elucidate the physico-chemical bases of grain quality characteristics, and how to breed for them, to continue.
- Adoption of improved maize varieties in Nigeria to be studied in collaboration with national scientists.
- Strengthening of national programs and regional networks to continue, emphasizing collaboration and transfer of technologies in breeding research, especially in screening for resistance to maize streak virus and *Striga*.

Cowpea

- Improvement of cowpea with stable resistance to flowering and postflowering insect pests to continue, using both conventional breeding and biotechnology.
- Improvement of local cowpea genotypes to continue, incorporating a stable resistance to diseases, insect pests, *Striga*, and *Alectra*, and adapted to mixed cropping systems with cereals (millet, sorghum, and maize) for the dry savanna.
- Improvement in cowpea grain types with a wide range of maturity periods to continue, to meet diverse needs in different agroecological zones.
- Technical support for national programs and networks of cowpea scientists in western, central, and southern Africa; emphasizing technologies for incorporating resistance to diseases and insect pests into local varieties. Priority given to collaboration with the Semi-Arid Food Grain Research and Development (SAFGRAD) cowpea network, and to support for the Southern African Development Coordination Conference (SADCC) cowpea project.

Soybean

- Breeding to continue for resistance to insect pests and early maturity (to provide an 80–130 day range of maturities) with other desirable traits, for different zones.
- Sources of resistance to frogeye leaf spot

disease to be identified, and the mode of inheritance of resistance to be determined.

- Maintenance breeding to retain the traits of stable and high yield, good nodulation with soil bacteria, resistance to the main diseases, nine-month storage capacity of seeds, resistance to buckling under the weight of high pod yields, and pod resistance to shattering and seed dispersal before harvest.
- Development of soybean as an ingredient in traditional food preparations, for domestic and small-scale industrial use, to continue in Nigeria and Ghana with national programs.
- Joint research on sorghum and soybean intercropping, and on crop rotation systems with soybean, to continue with the Institute for Agricultural Research, Samaru, and the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), with field testing in the Nigerian dry savanna.
- Investigation of nitrogen fixation potential of free-nodulating soybeans to continue with the Biological Nitrogen Fixation Technologies for International Development (NIFTAL) Project, University of Hawaii.

PRIVATIZATION OF NIGERIA'S HYBRID MAIZE SEED BUSINESS

IITA's hybrid maize research over the past 12 years has encouraged private sector development in Nigeria's seed industry. A number of maize seed companies have started operations in the country since 1984, with technical advice and germplasm from IITA. The four largest of them produced and marketed between 1,200 and 1,500 metric tons of IITA-developed hybrid maize seed in 1991.

These beginnings mark a new maturity in Nigerian agriculture, reflecting a commercial awareness that an increasing proportion of farmers, small- as well as large-scale, are ready to grow maize as a cash crop. The new seed companies are diversifying their markets with hybrid sorghum and improved varieties of cowpea, soybean, rice, vegetables, and industrial crops.

Of all the registered companies interested in hybrid maize seed business, four had productive operations in 1991:

- Agricultural Seeds Co., Ltd. (established in 1984 at Zaria, Kaduna State; bought up by Pioneer in 1992)
- Pioneer Hi-bred Seed Nigeria Ltd. (began production in 1990 at Kaduna)
- UAC Agro-Industries, of UAC of Nigeria Plc (initially a contract grower, began own production and distribution in 1989 at Zaria)
- UTC Nigeria Plc (began producing seed for mid-altitudes region in 1989 at Jos, Plateau State).

Hybrid maize combines qualities most desired by farmers and consumers. It can produce substantially higher yields with highly uniform grains, important for industrial consumers. Other characteristics can be tailored to suit growing conditions in specific areas; for example, resistance to specific dis-

High yields from hybrid maize make it an attractive crop for farmers with access to seed and fertilizer.

A harvest of young "green" maize.

eases and pests, and tolerance of drought or other stresses. However, hybrid maize brings overhead costs to the farmer: new seed must be purchased for each planting. The seed produced by a hybrid maize crop is genetically different from the parent hybrid, and loses its high yields and desirable characteristics.

The maize traditionally cultivated throughout the developing world is open-pollinated. Its own seed can be used for the next crop, unlike hybrid maize. It fits easily into the mixed cropping systems of traditional African agriculture, and can produce close to its full potential harvest with less fertilizer, labor, or other inputs than can hybrid maize. Subsistence farmers value these economical requirements.

Open-pollinated maize can be improved for higher yields, pest resistance, and desired grain quality. But, after cultivation over several seasons, the germplasm loses its yield potential and other traits through cross-pollination with other varieties growing in the vicinity. Hence, farmers must seek new seed with a high level of the desired characteristics, if they are to continue to realize the full potential harvest. The need to renew seed comes less frequently with open-pollinated than with hybrid maize. But the rewards are greater for opting for hybrid maize, with its substantially higher yield.

Savanna boom. During the 1970s, IITA breeders developed high-yielding, improved open-pollinated varieties called TZB, building on Nigerian composites. Released to farmers late in the 1970s, TZB varieties were resistant to the major fungal diseases and highly adapted to conditions in Nigeria's "moist savanna", which has a rainfed growing season of four to six months. A boom in modernized maize farming began: TZB spread rapidly across the savanna during the 1980s, as federal and state agricultural extension services made fertilizer and advice available. A nationwide highway system created new links for the savanna region with markets in the populous south. These developments created opportunities which farmers could exploit with hybrid maize.

IITA scientists expressed interest during 1977 in the possibilities of developing hybrid maize varieties suited to the nation's needs, which international centers were not pursuing at the time. During the following years IITA breeders took up the challenge and began crossing the best available germplasm with IITA maize streak virus-resistant populations.

Nigeria's federal government declared hybrid maize a high-priority crop in 1981 and contributed US$500,000 to IITA for research. By 1983, Nigerian scientists from three research institutes, three universities, and the national services for seeds, extension and accelerated food production joined IITA in hybrid selection trials. By 1984, experimental hybrids started on-farm testing. During that year, the first hybrid maize seed company, Agricultural Seeds, produced 80 tons of seed under IITA and National Seed Service supervision.

By 1990, hybrid maize farmers were harvesting 3 to 5 tons of grain per hectare, a yield advantage of about 15% over the earlier improved but non-hybridized varieties. Hybrid maize covered an estimated 100,000 hectares of the country's 2 million hectares planted to maize.

At first the federal government had to organize production of open-pollinated maize seed for the state projects to multiply for distribution to farmers. But bureaucratic operating methods are usually not well suited to catering for seed needs in a dynamic marketing situation, where location and scale of demand are changing. So, for hybrid maize, the government decided that privatization of the seed industry should be allowed to evolve, in order that production and distribution networks develop efficiently. Private-sector seed quality would be more likely to conform with farmer requirements than would seed quality from a government agency, because a private firm's survival depends on customer satisfaction.

An essential role for the government does remain, however, in enforcing quality standards for commercial hybrid seed, and in providing open-pollinated maize seed for resource-poor farmers.

Entrepreneurial investments in the seed industry are proof of success of public-sector investments in agriculture. The public sector needed to put up front the required research into hybrid maize and its on-farm production, as well as the infrastructure: the extension system, subsidized fertilizer, and roads. Because of their high costs and lack of immediate commercial return, those governmental investments are a prerequisite for a viable agricultural industry with private participation.

Entrepreneurial perception of the feasibility of a private seed business in hybrid maize also marks a crucial stage, a coming of age, in the country's agricultural development. Prospects for growth are enhanced when farmers recognize the importance of pure, high-quality seed as a regular input in their production efforts, and when they are prepared to take the investment risks for the anticipated gains.

Success for IITA from its own research investment has come, so far, in the general perception of hybrid maize as a crop for farmers in developing countries. Having proved viable in Nigeria, IITA's hybrid maize technologies of varietal characteristics and seed are being propagated through national programs in other West and Central African countries: Cameroon, Côte d'Ivoire, and Ghana, among others.

Private and public-sector enterprises in East and Southern Africa have also utilized IITA germplasm in developing their hybrid maize varieties: in Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zambia, and Zimbabwe.

A SOYBEAN PRODUCTION SURGE IN NIGERIA

HOW POLICY CAN PROMOTE THE RIGHT TECHNOLOGY AT THE RIGHT TIME

As the market grows in Nigeria for oilseed products, small-scale farmers are finding soybean an increasingly attractive crop—more so than competing oilseeds such as groundnut. Soybean does not require fertilizer to produce an adequate harvest, while its labor requirements fit well in the cropping calendar with the needs of other crops. At the same time its market price has risen faster than that of groundnuts. And IITA-improved soybean varieties have been available with higher yields, which have reduced the cost of producing the crop.

The increasing demand for locally grown soybeans stems from governmental policies to combat Nigeria's economic ills. The national currency, the naira, has devalued drastically, which has increased the attractiveness of homegrown over imported oilseeds. During the past five years importation of edible oils and soybean meal has been banned, which has stimulated local production of vegetable oils and oilseed cake.

Policy has given a special boost to soybeans over other oilseeds. Government and private groups have promoted soybean for its nutritional value, as a protein source, since other sources such as meat and eggs are beyond reach of most people.

Moneymaker. Soybean has been grown in Nigeria for the past half century. The British administration introduced a Malayan variety as an export crop during the 1940s, in an area farmed by the Tiv people in Benue state, where agroecological conditions favored production. Late in the 1940s the British set up a marketing board which purchased soybeans for export, unprocessed.

By 1960, when Nigeria achieved its independence, it had become a major world exporter of palm and groundnut oil. Palm oil and groundnut oil were being processed for local consumption at village level and for export. While soybeans were still being grown for export, there appears to have been no significant village-level processing or consumption of soy products.

Over the following decades, during the civil war and then the new wealth from petroleum exports, soybean farming declined.

Late in the 1960s civil war broke out, which hindered internal transport and the export of commodities. US Department of Agriculture records show average annual soybean exports from Nigeria of about 13,500 metric tons just before the civil war (1964-1965). Production declined during the war (1967-1970) to about 9,000 tons per year. During the years after the war through 1976, average annual exports amounted to 3,500 tons. From 1977, export figures decline to zero.

The petroleum "boom years" in Nigeria, from the mid-1970s to early in the 1980s, brought a prosperity which worked against agricultural development. The naira was overvalued, at greater than parity with the US dollar, making imports of oilseed products less expensive than local equivalents. Exports of soybeans and edible oils ceased, and exports of oilpalm kernels and groundnuts declined. After having been an exporter of edible oils for decades, Nigeria became an importer—increasing demand for oilseed products was met by imports, which included groundnut, palm, and soybean oil, soymeal, and groundnut cake.

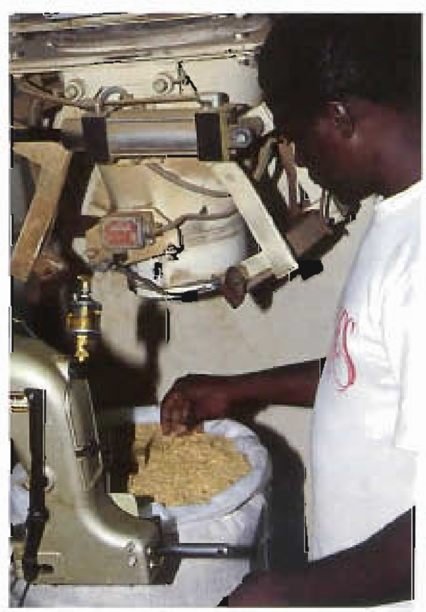
The imports of soy oil indicate that its domestic acceptance had begun, although the cheap imports discouraged domestic production. A small market for soybean did develop late in the 1970s, however, in Kaduna state. The makers of dadawa, a fermented seasoning, started to substitute soybean for locust bean, the traditional ingredient. Although limited, this source of demand for soybean helped to maintain production.

New support for a market for local soybeans came about in the mid-1980s, in the form of governmental macroeconomic policy, which pulled up the price of the crop. In 1986 the Nigerian government undertook a structural adjustment program (SAP) to stimulate economic recovery. The naira was devalued by 75%, to 4.00 naira per US dollar. Its value continued to slide, reaching 9.25 naira per US dollar by 1991. Under SAP, agricultural prices were deregulated and importation of major food commodities banned—including staple grains, edible oils, and soybean meal. The ban had its intended effect of giving a boost to local production of vegetable oil and oilseed cake. (Even though imports of unprocessed soybeans were not banned, local soybeans were more cheaply available and hence received a boost from the ban.)

Besides that policy pull, drought during 1983–1984 pushed up prices of all agricultural commodities, and increased substitution of soybeans in dadawa production which could be supplied more easily than locust beans. And during the mid-1980s, as SAP tightened the economic belt, public health and charity organizations campaigned to promote consumption of soybeans for their nutritional value. Soybean products began to become incorporated in traditional diets and processed foods.

With these market stimuli, a technical

Partially defatted soybean cake is bagged at a Benue factory for use as animal feed.



advantage which soybean enjoyed came into play. By early in the 1980s, IITA had achieved a research breakthrough in collaboration with Nigerian research and extension organizations, notably the Institute for Agricultural Research, the National Cereals Research Institute, and the Institute for Agricultural Research and Training. IITA scientists succeeded in breeding high-yielding soybean varieties that could accept the bacteria found in African soils and nodulate with them. Before this characteristic of "promiscuous nodulation" had been transferred to high-yielding soybeans, the seeds had had to be inoculated before planting, in a process that was too expensive and complicated to permit small-scale African farmers to grow soybeans.

Other problems had also been solved through breeding: curbing the tendency of pods to shatter and disperse the beans before they could be harvested, and reducing the time requirement for the crop to mature which was too long to suit rainfall patterns in savanna areas.

Technological advances from IITA, together with collaboration with national institutes in adapting the new varieties to local growing conditions, enabled farmers to make use of these improved varieties. Farmers could respond to the increasing demand for oilseeds by producing high-yielding soybeans, keeping their production costs low and their prices competitive with those of imported soybeans. Expansion of soybean cultivation was feasible because it required little labor and fertilizer, and it was compatible with existing intercropping systems. On the other hand, groundnuts were suffering from disease problems which limited their expansion, and oil palm—being a tree crop—could not be easily expanded. Soybean production could thus increase as its profitability became apparent.

Back to the future. Several IITA surveys of soybean-growing villages in Benue state, eastern Nigeria, and of soybean marketing in the town of Ibadan in southwestern Nigeria, have shown how soybean production has flourished within a conducive policy environment.

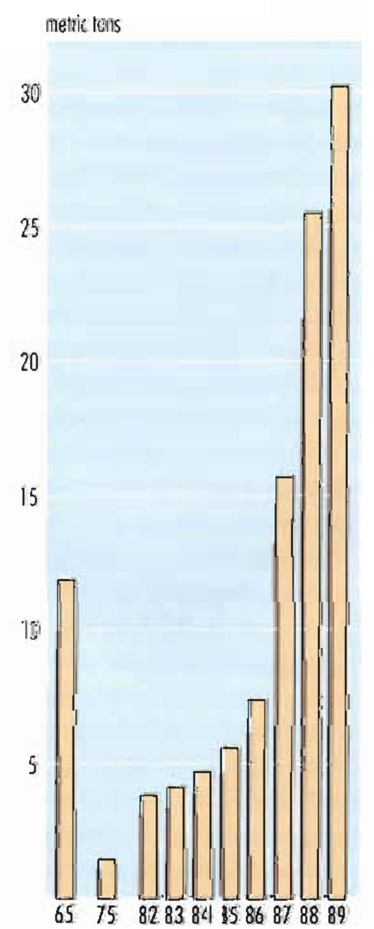
Benue was chosen for the production study because its history of soybean cultivation, which dates from colonial days, affords a perspective on effects of policy changes on production trends, and the Tiv farmers there have become experienced soybean growers.

In 1989, soybean was being cultivated in 75% of the 55 randomly selected villages, but was more widespread in the Tiv area (96%) than in the non-Tiv area (52%). Almost one-half the Tiv villages reported soybean to be a major cash crop, whereas it had been so in less than one-third of those villages before the civil war period, some 25 years earlier.

While profitability was the main reason given for producing soybeans in most of the Tiv and non-Tiv villages, the second most popular motive was recognition of soybeans' nutritional value and food use. Soybean was substituted for locust bean in the preparation of dadawa and for cowpea in several dishes. It is cheaper per weight than cowpea, and much more available than locust bean.

A sample of 70 farmers growing soybean in 1990 had produced a total of 30.4 metric tons of soybeans during 1989. The accompanying diagram shows the farmers' view of their own production from 1965 to 1989. They claim that they produced half the current harvest before the war. During the post-war period, their total production declined to 1.4 tons around 1975 and rose to 4.5 tons in the 1982–1985 period, just before the naira devaluation. Devaluation appeared to have had a tonic effect—production had swollen to 15.8 tons by 1987. And two years later it was nearly double that. This picture of production trends fits the US governmental record for the 1960s and 1970s.

TOTAL SOYBEAN PRODUCTION BY 70 FARMERS IN BENUE, NIGERIA



The production survey results indicate that farmers in the Tiv (eastern) part of Benue state were currently harvesting 30,000 metric tons per year, from virtually nothing after the civil war. Expansion largely occurred between 1986 and 1989, when three-quarters of current producers began cultivating the crop and many of the established producers (two-thirds) expanded their production. Soybean was also spreading in the non-Tiv (western) part of Benue, although at a slower rate. While the survey is based on farmers' memories, a clear picture emerges of large-scale increase and trends consistent with the US data.

The urban market survey in Ibadan, the town where IITA is located, revealed that soybeans were being sold in only two markets in 1987, but in 19 markets by 1990. Soybean retailers in those markets expanded from a total of four to 419.

Before the naira devaluation in 1985, only one of the current enterprises in Nigeria had been producing soy oil and seedcake, with an annual capacity of 500 metric tons. (Actual production figures are not available.) By 1989 six companies were producing oil and seedcake, with over 117,000 tons per year of capacity. Other companies were using soybeans to make traditional and new foods, including beverages, breakfast foods and baby foods.

Pivot. The Nigerian experience illustrates how government policy can, by turn, impede production and the adoption of improved varieties, then stimulate demand and encourage farmers to adopt new varieties. But, while the fortunes of soybean over the decades have pivoted on the nation's economic and social policies, other elements gave vital support to the phenomenal expansion of the crop during the past four years. Any assessment of soybean's future must take into account the policies as well as the other economic and agricultural factors.

Import bans on oilseed products led Nigerian mills to use local oilseeds, while currency devaluation made those oilseeds more attractive in the market. But soybean could become more competitive than traditional groundnut and oil palm because of improved, high-yielding varieties. Research had made these new technologies available early in the 1980s, but farmers took them up only after demand had grown and when prices would not be depressed by additional production. So an expanding market gave a push where policy pulled, and research provided the means for farmers to enlarge their response.

In deciding to expand production, farmers have considered the merits of soybean in terms of their own economy. Soybean may not yield as much profit as do other crops for the same amount of effort, but it may attract farmers because it suits their particular circumstances. They find the crop a convenient one in Benue, where land is abundant but labor is not. Less labor is required in growing soybeans than that for groundnuts or rice. Benue farmers also learned, after fertilizer supplies grew scarce during the 1980s, that soybean yields an adequate harvest without fertilizer.

Soybean may appear to be less labor-intensive because of the timing of its labor requirements in relation with the schedule for other crops. Soybeans are planted before the peak period of groundnut and yam planting, and are harvested before the yam harvest peaks.

Besides timing, its compatibility in intercropping with other crops attracts farmers. In Benue, soybean is intercropped most with sorghum, which is planted at low densities, and to some extent with cassava, which grows slowly and dominates the field after the soybean is harvested. Farmers find it benefits companion crops as a ground cover against weeds. Also, as a nitrogen-fixing legume, it provides a source of nitrogen fertilizer from the plant material discarded after harvest.

In tracing the connecting elements responsible for the recent soybean phenomenon, it is clear that increasing industrial demand has driven the expansion of soybean, within the framework of conducive policy and with the right varieties for farmers' resources and cropping systems. Farmers could take advantage of improved soybean varieties, once economic policy had made the market favorable for local production. In turn, rapid growth of soybean supplies after the mid-1980s encouraged the mills to rely on them in oil and feedcake production.

Whether soybean crops and industrial production can continue to develop in the same direction will largely depend on the policy environment—will the industry be viable, if oil and feedcake import bans are lifted? The market for local soybeans has shown signs of a strong growth potential, at current production cost levels.

Reinforcement. Promotion of local soybean products has helped, in Nigeria, to support rising market trends within a favorable economic environment. Governmental and private groups have popularized soybeans as a source of good and low-cost nutrition, while traditional alternatives have priced themselves beyond the reach of most.

Promotion and policy initiatives appear to be working hand in hand in other areas of Africa, to develop a soybean industry. In West Africa, a Ghanaian national committee is campaigning to increase production and utilization of soybeans. The crop has been grown in savanna areas of the country for many years, and is being expanded in other parts. Women's groups, among others, are supporting the national campaign with local activities. In neighboring Côte d'Ivoire, the government is stimulating production in the moist savanna.

In southern Africa, small-scale farmers in Zambia have been expanding production of soybeans with support from the government and cotton growers' groups, which are also promoting household and commercial utilization to provide a market for the crop. In Zimbabwe, soybean has long been a crop for large-scale farmers. Now a local researchers' group is introducing ways for small-scale farmers to produce it.

Success for soybean has been the outcome of a synergy of forces: economic, technical, and social. The current favorable environment will enable increasing numbers of people to enjoy the healthful benefits of this golden bean.

ACCELERATING THE FLOW OF CASSAVA GERMPLASM

Cassava scientists at IITA are developing ways to accelerate the delivery of new cassava germplasm to national programs. Biotechnological techniques may be able to replace more time-consuming procedures required for disease-free certification for international shipment. Techniques are being worked out for managing the establishment of cassava plantlets in nurseries and fields in-country, to promote survival of materials for adaptive research.

In recent years, IITA has been breeding new genotypes targeted on farming needs in the main growing areas. Careful selection for desirable characteristics over the years has produced a large number of genotypes ready for delivery to national programs. With the help of "management" solutions to reduce delivery time requirements, IITA's cassava program hopes to build its delivery rate of improved germplasm up to 50 clones per year for each of the main zones in the region.

New impetus to step up the flow of germplasm has come from the results of the Collaborative Study of Cassava in Africa (COSCA) released during 1990 and 1991. COSCA confirms that cassava has become more than just a backyard crop to keep hunger at bay—it is a cash crop for many farmers and a low-cost food staple for town-dwellers. From the results it is also clear that the number and extent of new varieties being cultivated by farmers trails behind the amount of improved germplasm ready for use in in-country research. Hence, cassava researchers share a new concern to accelerate the pace of improvement research in Africa's "cassava belt" countries (see map on p. 16).

Delivering the goods. Germplasm embodying a new genotype is usually conveyed to national programs as a plantlet, in a disease-free state inside a sealed flask. IITA has developed this technology for transmitting germplasm which satisfies phytosanitary requirements. Plantlets are also an efficient form for use in field research, because vegetative propagation is the easiest way to replicate the particular set of genetic traits of a desirable cassava variety.

Plantlets are produced in the flasks by culturing the growing tips of selected cassava genotypes in a sterile medium. Next, each plantlet is subjected to a process of "virus indexing" and quarantine inspection, after which it may be declared virus-free and ready to ship to IITA collaborators. (The chart opposite depicts the time scale of the tissue culture and virus-indexing process.) Conventional virus elimination and indexing take at least eight months, which puts a brake on the flow of material to national programs. But quarantine regulations must be met, for the benefit of all concerned, so any means to accelerate the flow must involve certification of healthy plantlets.

IITA has begun to investigate alternatives to the effective but lengthy indexing process. The biotechnological techniques of polymerase chain reaction (PCR) and CDNA probes are promising applications. Such screening techniques may be able to help complete virus indexing within a fraction of the time previously required.

In addition to use of biotechnology to speed up the virus indexing process, another set of procedures is being revised: "post-flask management" of the cassava plantlets in the recipient country. Too often the tissue culture materials are lost in transplanting to nursery beds.

A delicate cassava plantlet ready for transplanting and conditioning to a normal growing environment.

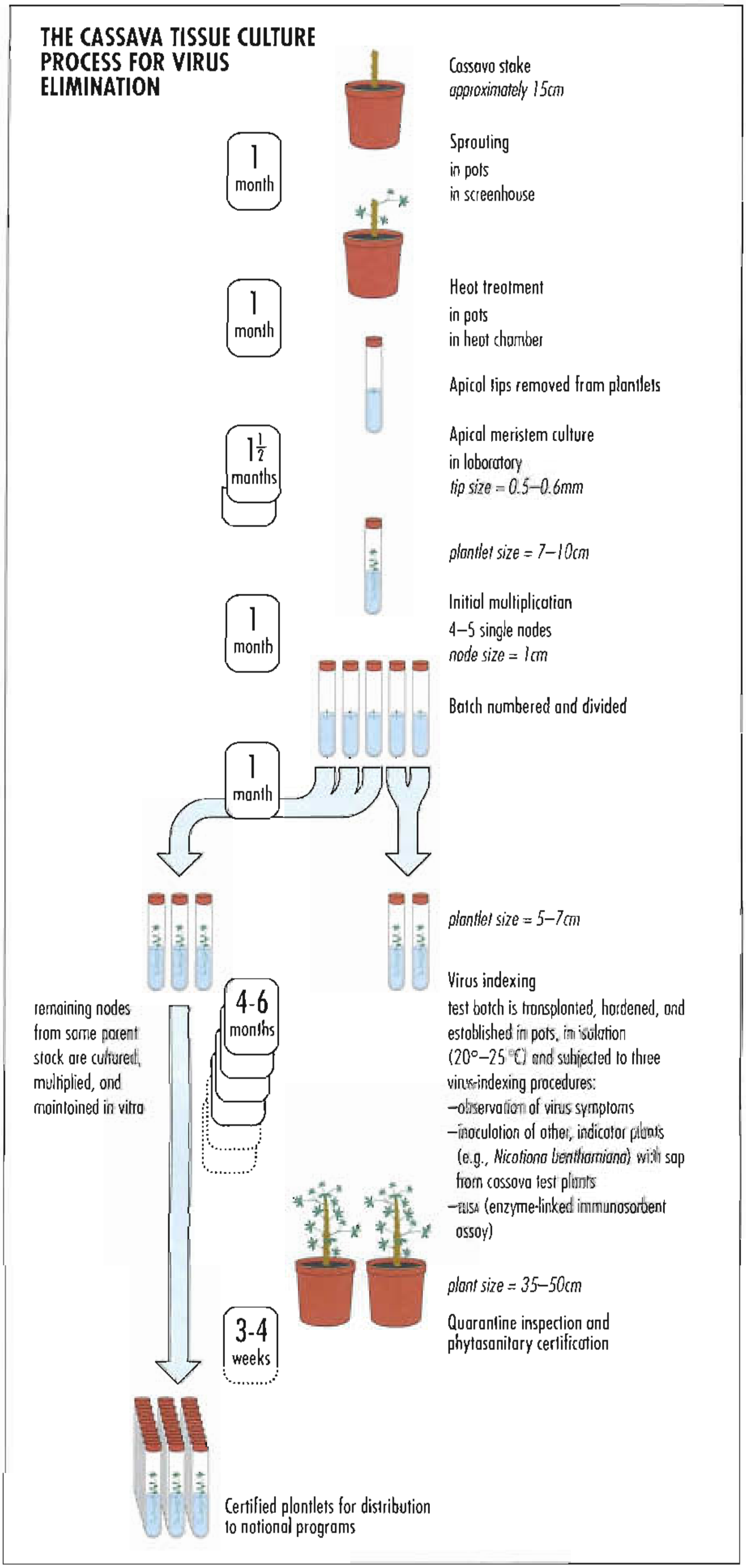
The plantlets arrive in flasks which have provided a sterile, humid environment. They are at a tender stage of development and must be conditioned gradually to the drier, harsher conditions of a research nursery. They must be permitted to adjust to a normal growing environment, and to develop their defenses against local pathogens. Four to six weeks are normally sufficient for a plantlet to establish itself in a nursery bed under research conditions.

With every shipment IITA provides "jiffy pots" with a transplanting medium of peat moss and vermiculite, a highly water-absorbent filler material. Each plantlet should be transplanted into this medium in the jiffy pot as soon as it is removed from its flask. The jiffy pot should in turn be planted in a larger pot, or directly into the nursery bed, where it will gradually decompose, leaving the growing plantlet to continue its development in the chosen research site. Problems arise where the transition from flask to pot and external environment is too abrupt because of environmental or handling problems. The consequence in many instances is a plant survival rate too low to be of benefit to the receiving program.

IITA has begun to address this management problem by exploring ways to adapt methods of establishing plantlets under specific local conditions. A low-cost humidity chamber is being designed, to be made on site of locally available materials, which can provide the newly transplanted cassava with some transitional protection.

Long-term goals. The current adjustments in IITA's delivery strategy are aimed at two long-term goals. One is to extend the use of improved cassava genotypes in research programs in all cassava-belt countries. The other is to develop national capability in breeding improved varieties from seed, which permits a full range of genetic exploitation.

IITA has bred many new cassava genotypes to produce high yields under different growing conditions in West and Central Africa's main agroecological zones—the humid for-



THE CASSAVA TISSUE CULTURE PROCESS FOR VIRUS ELIMINATION

est, the forest-savanna transition, the moist savanna. Breeders are also developing new genotypes for other zones, where cassava production has recently shown increases—coastal areas, mid-to-high altitudes, and the dry savanna.

Areas typifying all these zones can be found in Nigeria, so IITA breeders have been able to develop genotypes which can be targeted to similar environments in other countries with the same kinds of requirements. IITA uses breeding sites in Nigeria representing the humid forest region (at Onne), the forest-savanna transition zone (Ibadan), the moist savanna (Zaria), the dry savanna (Kano), and the mid-altitudes (Jos).

A new site, characteristic of higher altitudes, will be established at Bvumbwe in Malawi during 1992, because a high proportion of the cassava of eastern and southern African countries is cultivated at mid-to-high altitudes.

Resistance to particular diseases—for example, cassava bacterial blight and African cassava mosaic disease—and more recently, resistance to the insect pests cassava mealybug and cassava green mite, have been high among breeders' priorities. Early maturity of the crop has become an important characteristic in breeding cassava for farmers who will sell their produce.

Processing and eating quality characteristics have joined these breeding priorities as consumer preferences have become more widely known. For example, most improved cassava varieties grown in Nigeria have a firm and smooth or "waxy" texture, which is suitable for grinding into flour or the popular "gari". However, in countries where consumers boil and eat their cassava, they prefer the flesh to have a mealy rather than waxy texture.

Eventually breeding research must graduate from the early test sites to targeted areas of release, in order that clones of improved genotypes can be adapted to local conditions. The genetic material being delivered must suit the needs of recipient programs, must be in sufficient quantity, and must come in a form within the recipient's capacity to develop. These are the issues which IITA's cassava program is currently addressing.

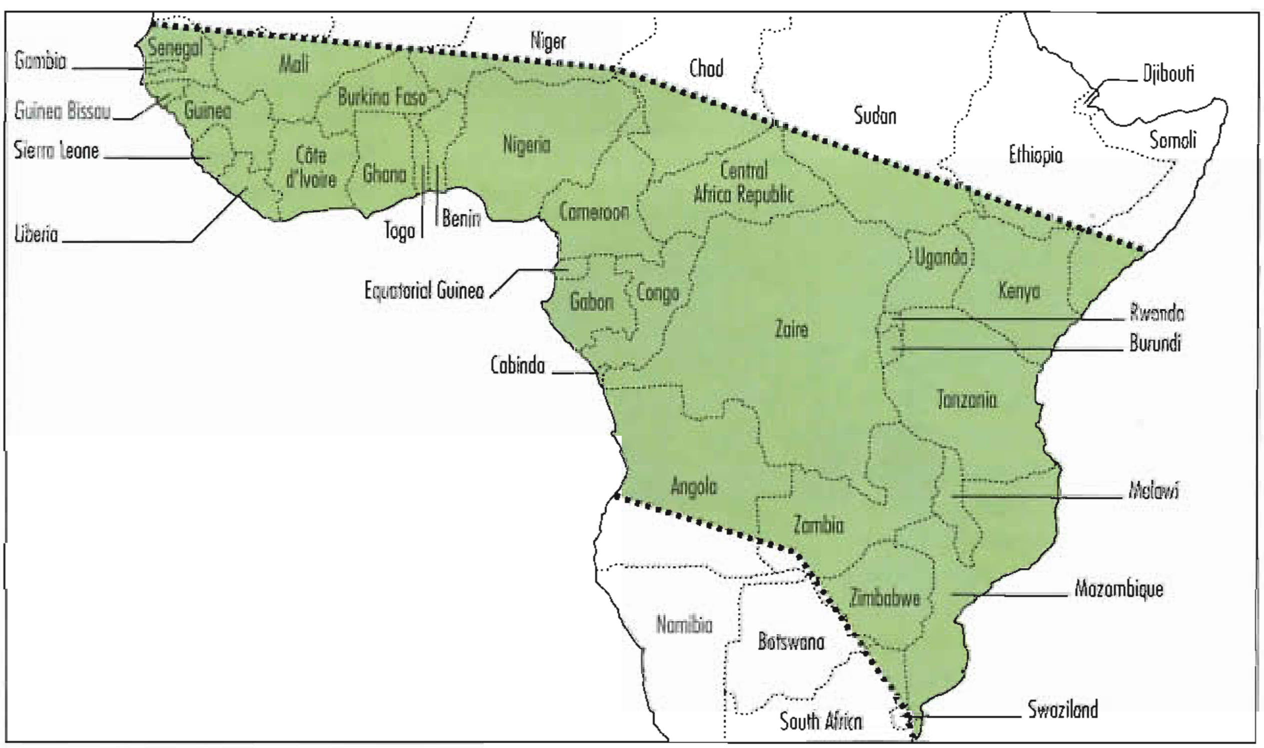
Best from seeds. To make the best possible use of the vast genetic resources available from IITA, cassava breeders should be able to work directly with seed populations. Cassava seeds contain the genetic range from which breeders can select and produce new genotypes for their particular needs. Seeds are also the easiest form for transmitting germplasm from place to place, and the safest in terms of disease prevention. The difficulty, however, lies in coping with the variability in genetic traits expressed in cassava from one generation to the next—as well as in providing for the gamut of facilities and expertise which is required in breeding from seed.

Most national programs can take a semi-finished, tissue-cultured product through the final testing stages, and release it if it fills their needs. But it takes five years for IITA, in the first place, to select and produce a genotype as a tissue culture, for transmittal to a national program. Moreover, the recipient is restricted to the set of genetic traits expressed in that plantlet. IITA's goal is to enhance the breeding capability of collaborating African programs, to enable them to exploit the available genepool on an independent basis by using seeds. They can thereby save years in the selection of genetic material best suited to their needs.

With the help of technical support from IITA and allied institutions, a number of countries have already developed the capability to use cassava seed in producing new varieties for release to their farmers. The prominent examples in the following paragraphs have also been able to provide germplasm or finished varieties to neighboring countries with similar needs.

- Cameroon has used improved cassava seed from IITA and locally collected germplasm to breed new varieties, which yield in some cases more than double the harvest of the best local varieties. An in-country network was established among research groups, development projects, and farmers, to transfer technologies to farm level and address issues in training, on-farm testing, multiplication, and distribution. Cameroon has shared its expertise and germplasm with other Central African countries in networking activities, and has sent some of its genetic materials to Equatorial Guinea and Central African Republic for their research use.
- Rwanda has developed its own improved cassava populations on an extensive scale, from germplasm collected locally and imported from IITA and elsewhere. An in-country network links development projects and activities throughout the country in multiplying and distributing new cassava varieties to farmers. Rwandan researchers have disseminated their material widely among colleagues in the other 10 member countries of the East and Southern Africa Root Crops Research Network (ESARRN), which IITA helped to found in the mid-1980s.
- Sierra Leone has imported IITA-improved cassava seed and used it together with seed from their local collections, to produce genotypes which are adapted to their agroecological conditions. Sierra Leone cassava scientists were able, in 1991, to plan a program to help colleagues in neighboring Guinea by sending semi-finished material for their own field trials and selection. Sierra Leone teams have made advisory visits and donated germplasm to Guinea, Guinea-Bissau, and the Gambia.
- Zaire has utilized improved seed materials from IITA in producing high-yielding and disease-resistant varieties which became popular with farmers for good eating quality of tubers and leaves. Zaire has provided germplasm to the Congo, and a Zairean breeder is helping to develop the cassava program in Malawi.

AFRICA'S "CASSAVA BELT"



Research in Zaire has produced high-quality tubers from IITA seed materials.

• In addition, national root crops improvement programs in Benin, Gabon, Ghana, Liberia, Malawi, Nigeria, and Togo have also effectively utilized seeds of IITA-improved cassava in breeding their own varieties for widespread release in-country. Farmers from these countries and others in West and Central Africa are participating with scientists in testing clones of improved cassava from IITA and national sources. Scientists, farmers, and extension agents are being trained in rapid multiplication techniques, in order to increase availability of planting materials of improved clones.

In developing its cassava improvement program, IITA has exchanged germplasm with Centro Internacional de Agricultura Tropical (CIAT), which holds the world's largest cassava germplasm collection. IITA and CIAT are introducing genetic material from different environments in South America, the home of cassava, as well as hybrids with Asian germplasm, for adaptation in corresponding agroecological zones in Africa.

Cassava improvement in Africa links many countries at different stages of program development, in collaborative efforts that have already scored notable successes. In order to accelerate the pace of selection and release of new varieties for their farmers, they should be working with a larger volume and range of germplasm than they are receiving, including seed and vegetative materials. Many of them also need help in managing the on-site establishment of test materials. IITA cassava scientists believe that their most important task now is to address these practical needs of their collaborators, in enabling them to expand their own capacities.

PLANT HEALTH MANAGEMENT

IITA's Plant Health Management Division engages in basic and applied research on crop/pest/environment interactions, in partnership with national programs of sub-Saharan African countries. The Division develops and implements ecologically sustainable interventions for African farming systems, to provide solutions to today's plant health problems and prevent those of tomorrow.

RESEARCH DIRECTIONS

Reorganization of institute-wide plant protection activities within the new Plant Health Management Division. Emphasis on holistic understanding of pest/crop/environment agroecosystems as the basis for problem-solving research. Approach based on systems analysis with simulation models, and interventions in biological control, host plant resistance, and habitat management.

Cassava

- A major project on environmentally sound, ecologically sustainable plant protection for cassava to begin in four African countries and Brazil jointly with CIAT.
- Cassava mealybug: followup work in areas already controlled. Special efforts to be mounted in newly infested areas.
- Cassava green mite: releases of predators in main agroecological zones. Multiplication, release, and monitoring activities to begin in several national programs.
- African cassava mosaic virus and cassava bacterial blight diseases: research on the epidemiology and nature of their threat to cassava production.

Plantain

- Emphasis on host plant resistance to and epidemiology of black sigatoka disease.
- Assessment of impact of weevils and nematodes and potential for biological control. Project to continue providing basic ecological, biological, and socioeconomic data on most important production constraints in Central Africa and East African highlands.

Yam

- Evaluation of research needs, based on review of constraints and capacities of national programs.

Maize

- Research on resistance mechanisms and potential of host plant resistance to stem borers, in combination with biological control.
- Maize streak virus: resistance genes to be introduced into new varieties, particularly in southern and eastern Africa.
- *Striga*: research on the biology and epidemiology of the parasitic weed and its distribution and impact.
- Downy mildew: research on taxonomy, mass production, and host plant resistance.

Soybean

- Emphasis on frogeye leaf spot and red leaf blotch diseases. Other diseases and pests and their potential impact to be studied.

Cowpea

- Cowpea pest complex: development and execution of a sustainable, ecologically sound cowpea protection project based on data from many countries. Exploration, quarantine, introduction, and experimental release of natural enemies of cowpea thrips.
- Neem: use of neem oil against grasshoppers and cowpea pests to be developed.

Postharvest pests

- Postharvest studies: study of interactions between pre- and postharvest pests in local storage systems; also, socioeconomic influences on harvest and storage practices.
- *Aspergillus flavus*: survey of incidence to be conducted and aflatoxin extraction method to be developed.
- Larger grain borer: ecosystems research and exploration for natural enemies in Mexico (area of origin) and Honduras as a basis for a biological and integrated control program.

Other pests and weeds

- Locusts and grasshoppers: development of microbial control of locusts and grasshoppers. Multiplication techniques for pathogens to be developed for transfer to national programs. Large-scale field trials and adoptability studies to be conducted.
- Mango mealybug: followup on results of biological control by one parasitoid, and introduction of a new parasitoid from India for areas still infested. Impact to be assessed.
- Water hyacinth: introduction and release of natural enemies to continue.
- Weeds: Assessment of biological control to suppress major weeds.

Support

- National program support: special funding available to assist 15 countries. Emphasis on human resource development through degree and technical training. In-country training courses, involving researchers and extension workers, to be offered in addition to specialized courses at headquarters.
- Support services: insect museum and seed health services to be developed.

PLANT HEALTH FOR SUSTAINABLE AGRICULTURE

Guided by a concern for practical measures that national programs can adopt and support, IITA is developing its approach to protecting crops through the management of plant health. The focus on health reflects holistic thinking about ecological systems, while a management approach invites technological solutions.

The concept of plant health has evolved from the systems perspectives developed by ecological thinking and experience. Plant health is judged by the plant's ability to realize its biotic potential within constraints imposed by the various elements and conditions in the growing environment. A plant's health can be measured by its susceptibility to, or tolerance of, depredation by pests (including insects, mites, nematodes, diseases, and weeds). In such a perspective, plant protection efforts take the form of management of the agroecosystem constraints. The aim is to promote the plant's ability to achieve its optimum health level and, therefore, greatest possible productivity.

Ecologically oriented plant protection is bringing together ecologists, entomologists, plant pathologists, and weed scientists to address pest outbreaks as problems of ecosystem management. Pest outbreaks should not be treated incrementally as problems for host plant resistance, biological control, or agronomic practices and habitat management. The need for self-sustaining solutions to pest problems has motivated the interdisciplinary effort. Interventions that disrupt ecological functions are minimized in favor of technologies which promote ecological stability and agroecosystem resilience.

Such an approach also accommodates actions to restore and sustain the natural resource base, which is rapidly becoming degraded under crop production by inappropriate technologies. New pest problems are fostered where intensified production is permitted to erode environmental stability—especially by monocropping varieties with a narrow genetic base and high needs for fertilizers and pesticides.

Right for Africa. This approach to plant health management is particularly suited to agroecosystems in Africa, where small-scale farmers produce a diversity of locally adapted crops with few resources other than their own labor.

Plant health management in such a setting aims to maintain good crop productivity within the dynamic balance of forces in the agroecosystem, using a combination of plant breeding and systems management strategies. This ecological approach to crop protection seeks to eliminate the need to use environmentally hazardous pesticides, whose toxic residues jeopardize the integrity of the food chain and purity of water resources. Pesticides, a purchased input that would constantly have to be renewed, can also be an economic burden for farmers.

Moreover, the ecological approach works to conserve and enhance the efficacy of the pests' natural enemies. Pesticides generally have a more devastating impact on natural enemy populations than on the target pest—they destroy those "friends of the farmer" as well as deprive them of their food source, the pest itself.

Here, plant health management differs from integrated pest management (IPM) as it is currently practiced. IPM integrates genetic resistance, biological control and cultural practices with the judicious use of pesticides. Plant health is the logical evolution of IPM toward a more sustainable ecologically and economically sound approach.

In managing plant health from an ecological perspective, the first step is to gain an understanding of the dynamics and the biotic potentials of both plant and pests in the farm setting, and their key interactions, which will reveal opportunities for management intervention. The research should be a team effort, among scientists of various disciplines as well as extension agents and client farmers. Computer-based simulation models help in the analysis of the agroecosystem with its pest/plant/farmer interactions. The models can help develop appropriate technologies to achieve plant health—that is, to keep pest populations at below economic damage levels without any additional intervention.

Protection for cassava crops in Africa, where cassava has been introduced from its native South America, was initially based on

Researchers explain to a Beninoise farmer how a "trap" crop planted beside the main cowpea crop attracts specific insect pests and thereby protects the cowpea.

breeding improved varieties with resistance to the two major diseases, African cassava mosaic virus disease and cassava bacterial blight. The results have been a lasting control over these former scourges.

But the need for a broader management strategy grew during the 1980s, as two exotic pests, the cassava mealybug and cassava green mite, spread in devastating waves over the countries of tropical Africa's "cassava belt". The mealybug and mite come from the same environments in South America as cassava. There, their populations do not grow to epidemic proportions because natural enemies hold them in check. The solution for insect and mite pests was found in biological control, which approximates the original ecological equilibrium between host plant, pest, and natural enemy populations.

The success of IITA's biological control campaign against the cassava mealybug had, by the 1990s, turned the project into a model for environmentally sound and economically feasible protection for important food crops in African farming systems. The cumulative experience with a dual strategy, of resistance breeding and biological control, has provided the practical basis for effective plant health management which is durable and sustainable within the African agricultural setting.

Evolution. Research, training, and implementation of control activities for several crop pests have helped evolve the current management strategy for plant health aimed at IITA's long-term goal of sustainable food production. In 1979, the need for an added dimension to resistance breeding led to the formation of an Africa-wide biological control project at IITA, which had grown by the mid-1980s into the Biological Control Program. In 1991 these developments culminated in the establishment of the interdisciplinary Plant Health Management Division, which is dedicated to sustainable plant protection.

Sustainable plant protection technologies can be grouped into three types of interventions: biological control, host plant resistance, and habitat management.

- Biological control can follow three strategies: (a) classical biological control, whereby ecologically adapted natural enemies are introduced from the area of pest origin to the target area; (b) conservation of natural enemies present in the ecosystem, through cultural practices that enhance their activity; and (c) artificial augmentation of local natural enemy populations.
- Host plant resistance, using the introduction of various plant characteristics through breeding, is widely used and was once the backbone of plant protection research at IITA. In recent years this approach has been strengthened through biotechnology applications, which hold promise of accelerating transfer of useful genes within and across plant species. Biotechnology may be able to assist in overcoming natural barriers in the improvement of plant resistance to pests.
- Habitat management and agronomic practices for enhancing crop production are well known, but those for controlling pests are poorly documented. In Africa they have hardly begun to evolve as means for coping with the threat of exotic pests and diseases, although traditional slash-and-burn cropping evolved partly to help overcome weed problems. Systems research and good agronomic practices already point to a few, including selection of planting material free of pathogen and pest contaminants, or high-quality seeds. Fallow management can reduce undesirable weeds, while maintaining desirable refuges for natural enemies.

Many ecological and socioeconomic constraints to crop production also affect plant health management. The weather varies unpredictably. Water is insufficient in some places or seasons. Farm sizes are small, sometimes fragmented, with uncertain conditions of tenure. Harsh living conditions engender poor health among farmers. Women farmers are subjected to less certain land tenure than men, less access to credit, and greater restrictions in making decisions about their own crops.

Implementation of most plant protection technologies requires help from farmers and such agroecosystem managers as extension agents and researchers. Such a cadre of managers, properly trained, is needed to pass the knowledge and technologies along to the greater farming population, and also to complete the feedback loop to the scientists. However, given the day-to-day problems facing farmers, their involvement must be commensurate with the gravity of the biological and socioeconomic constraints being addressed.

A hopeful sign is the considerable national capacity in biological control which has been assembled throughout sub-Saharan Africa over the past decade. This capacity provides a basis for new work in classical biological control and for developing other plant health interventions. Such activities in each country will contribute to the development of environmentally sound plant protection all over Africa, on which the future of sustainable crop production depends in large measure.

THE SEARCH FOR THE RIGHT MITE

FINDING NATURAL ENEMIES FOR THE CASSAVA GREEN MITE IN AFRICA

After seven years of effort at biological control of the cassava green mite in Africa, where it was accidentally introduced from South America, IITA scientists have established two of its natural enemies, mite-eating mites, in representative areas of Africa's cassava-growing zones. Their success has stemmed from application of ecological principles in searching for and selecting natural enemies of the pest in its homeland.

While control of the pest may eventually involve a complex of enemy species, the achievement marks a scientific breakthrough: the first time that predatory mites have been used in the tropics against a serious mite pest of a major subsistence crop.

Farmers, especially those who plant mite-susceptible cassava varieties, will quickly be able to appreciate the impact of this achievement in their fields. In South America, research has shown that natural enemies protect cassava crops from one-quarter to one-third of the losses normally inflicted by the cassava green mite. In Africa, experiments indicate that the pest attacks reduce yields of improved cassava varieties by 30% at 12 months after planting, and by more after longer periods.

The cassava green mite (*Mononychellus tanajoa*) is thought to have come to Africa from Colombia, in a shipment of infested cassava planting materials. First sighted in Uganda in 1971, it quickly spread up and down the East African coast and within eight years had penetrated as far west as Nigeria. Today it is found in almost all the countries of Africa's "cassava belt", where more than 200 million people depend on cassava as a staple food.

***Typhlodromalus limonicus*, a predator mite of the cassava green mite.**

The toll is severe—up to 80% yield reduction in infested fields. The pest now threatens production in areas where cassava may be the only food in drought years. It feeds on the undersurface of young cassava leaves throughout the year, sometimes causing them to mottle, dry out, and drop. Heavy attacks can defoliate a plant, but rarely kill it.

Early efforts to control the cassava green mite, during the 1970s, included use of chemicals and preventive cultivation practices, as well as breeding to improve the cassava plant's resistance to the mite. After a decade's work had yielded no practical results, however, a new approach was clearly needed.

Case for biological control. The explosive outbreaks of the mite during the dry season in parts of the cassava belt suggested that local enemies were few, or not well adapted to it. An ecological imbalance appeared to exist, which classical biological control could redress.

Firstly, as an exotic pest, the cassava green mite would presumably have natural enemies in its homeland which could be imported to control the pest as they did back home. Secondly, biological control posed an ecologically safe, pesticide-free solution. It also seemed to be economically viable, given focused leadership by IITA, essential coordination with national and global institutes, and funding prospects from interested donors. Finally, the expediency of a biological control operation was compelling—the widespread nature of the problem called for a solution with minimal interventions by farmers, or by government extension services, because neither had the resources to devote to a control effort.

Similar reasoning had earlier led IITA scientists to embark on an Africa-wide biological control project against another major pest, the cassava mealybug (*Phenacoccus manihoti*). The mealybug is also native to South America, but was first discovered in Zaire in 1973. How and when it came to Africa is not known, but it spread rapidly throughout the African cassava belt after its discovery. The IITA-led campaign began in 1980. Within 10 years it reduced the cassava mealybug threat to negligible levels in most of the affected countries, by establishing natural enemy species from the pest's native land. Biological control of the mealybug continues today in the form of a "firefighting" force, to lend help to countries when fresh outbreaks threaten to get out of hand, especially along the leading edge of the dispersing population. It is also mobilized as a training resource for strengthening of national programs. (See article entitled "New support to sustain the success" in these pages.)

In 1983 research began on the biological control of the cassava green mite, with a focus on suitable candidates among natural enemies in its original environments in Colombia. As was the case in the cassava mealybug project, serendipity led exploration and selection at first—nothing was known at that time about Neotropical natural enemies of the cassava green mite. Unlike the good fortune of the earlier project, however, few of the initial enemy selections survived their African releases for long. Why?

This puzzle prompted IITA to characterize the natural enemy complex and identify candidates for experimental releases that would suit the pest situation in Africa. The tactic was to relate ecological principles to IITA's in-depth understanding of the key interactions in the African cassava agroecosystem, gained over the preceding five years, in the search for enemies in equivalent environments. Finally, by 1991, after adjusting the foreign exploration protocol and shifting emphasis to northeastern Brazil, IITA scientists succeeded in establishing two species of predaceous mites in a range of African cassava habitats.

Getting the right mite. A complex of efficacious natural enemies, combined with rainfall and locally adapted cassava varieties, prevents the cassava green mite from damaging the crop in South America to the extent it does in Africa, where efficient enemies are absent and local varieties have not been selected for mite resistance. The main problem was to select the right enemy species that would fit in the African cassava agroecosystems and do the job.

In 1983 IITA's Latin American sister institute, Centro Internacional de Agricultura Tropical (CIAT), began cooperating with IITA in a search for suitable enemies. Over the next five years, CIAT sent to IITA a selection of promising species of predaceous mites of the Phytoseiidae family from Colombia. Phytoseiid mites have generally shown a good capacity to control plant-eating mite species. Apart from phytoseiids, other natural enemies include spiders, insects, and pathogens. But often they are less effective control agents since they attack the cassava green mite only when populations have reached relatively high densities.

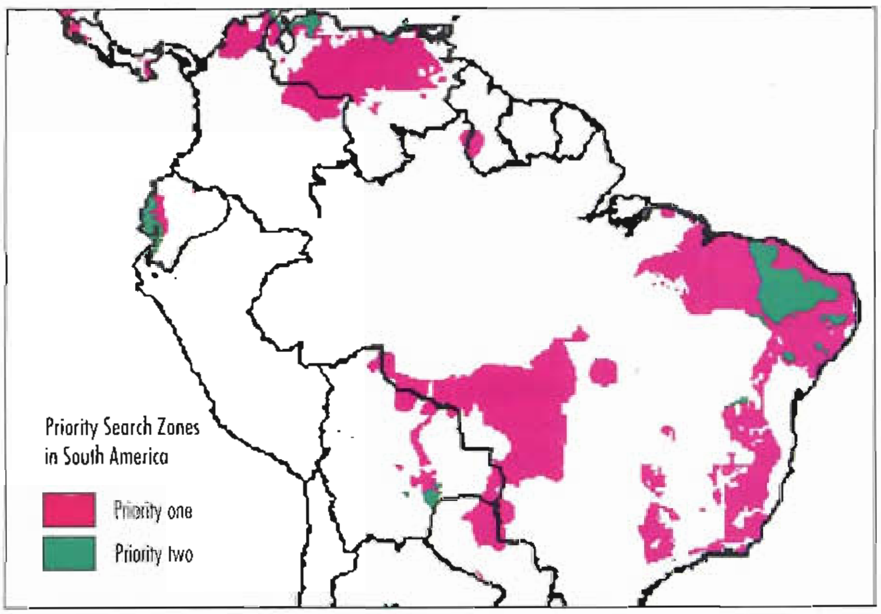
IITA engineered an elaborate international network of activity to select and send phytoseiid populations from South America for multiplication and release in Africa's cassava belt. All shipments of phytoseiid enemy mites passed through quarantine facilities in Europe before being forwarded to IITA, following guidelines of the Inter-African Phytosanitary Council of the Organization for African Unity (OAU). IITA developed procedures to support mass rearing of phytoseiids in Africa, and protocols for packaging and shipping them for experimental releases.

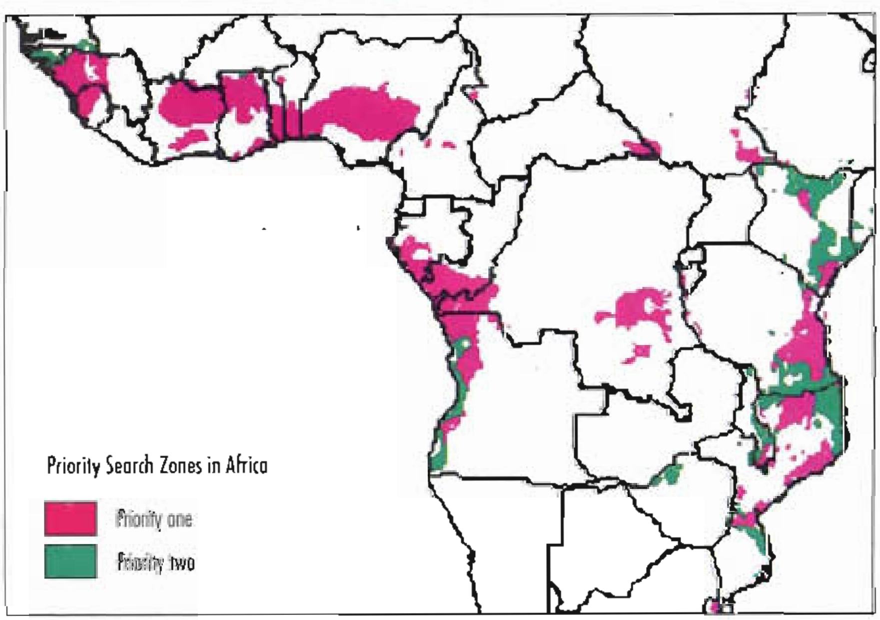
Field locations for African releases had to meet a combination of ecological requirements. The release sites were chosen to provide a high diversity of vegetation apart from planted cassava, including other crops, weeds, and trees, which would help the predatory mites survive by affording them alternative food sources. The sites were also selected for the presence of moderate population densities of cassava green mites. Releases were often timed for the beginning of the dry season, when the predators would have the best chances for survival on an increasing prey population. Ideally, the sites would be farmers' fields with more than 300 cassava plants of the same variety. The cassava in the release fields would usually not be ready to harvest for another six to 10 months or more, during which time the establishment of the new predator population could be monitored.

Stretching its production and logistical capabilities in a tremendous team effort from 1984 to 1988, IITA with its national collaborators released about 5.5 million individual mites, from seven different species of Colombian origin, in 10 African countries. Four of the species were found for a time during dry seasons, but invariably disappeared during wet seasons—none of the predators ever became established.

Ecological keys. As IITA and CIAT scientists studied conditions governing outbreaks of the cassava green mite in Africa, their understanding of the pest's biology and ecology grew and could make natural enemy selection more effective. This knowledge of potentially limiting ecological factors helped to set crucial selection criteria: incidence of candidate predators on cassava crops, their prey preferences, and their climatic suitability.

As a result of these agroecological systems analyses, exploration in South America probed new areas which corresponded, in





Priority areas in the search for the natural enemies of the cassava green mite in South America (above) which are homologous with indicated areas in African cassava-growing countries (below).
These areas correspond with habitats of the cassava green mite on both continents. Priority one: lowland forest-savanna transition and moist savanna (4–6 dry months per year). Priority two: lowland dry savanna (7–9 dry months per year). Annual mean temperature is greater than 22°C in both areas.

environmental terms, with African areas where the cassava green mite thrived. These ecological "homologues" were defined by agrometeorological conditions: temperature, solar radiation, rainfall, and soil moisture.

In the new exploration phase, IITA and CIAT were joined by the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) of Brazil. They focused on phytoseiids associated with the pest in both time and space, and which could feed and reproduce successfully on this prey. By 1991 these explorations had identified more than 50 phytoseiid predators and one pathogenic fungus as potential biological control agents.

The new strategy immediately yielded useful results. EMBRAPA was able to locate two Brazilian predatory mites, *Neoseiulus idaeus* and *Typhlodromalus limonicus*, which IITA multiplied and began to release during 1989. Through 1990 about 1.9 million of the Brazilian phytoseiids were released at a total of 133 sites in six countries, with the help of national programs in West Africa (Benin and Ghana), Central Africa (Zaire), East Africa (Burundi and Kenya), and southern Africa (Zambia). Another 1.1 million of the two species were released in Benin, Burundi, and Zaire during 1991.

Success in establishing the exotic phytoseiids was confirmed by routine follow-up surveys during 1989, 1990, and 1991 which measured their survival at earlier release sites. *N. idaeus* and *T. limonicus* were recovered in West Africa (Benin and Ghana) and East Africa (*N. idaeus* in Kenya, *T. limonicus* in Burundi).

Confirmation that an introduced species has established itself in a new environment comes with recovery of the species in the release fields after several successive cycles of potentially limiting conditions, such as different seasons, shifting food supply, habitat disturbance or non-biological catastrophes. Known as the recovery frequency, this proportion in Benin for *N. idaeus* was 0.61 (being recovery of *N. idaeus* in 61% of all the release fields). Recoveries continued to be made during a mean period of six months and a maximum of (thus far) 18 months. (At a conservative estimate of 2.5 generations per month in the field, a sample recovered after 18 months would be in its 45th generation.) For *T. limonicus*, the recovery frequency in Benin was 0.73, with a mean recovery period of four months and a maximum of 11 months. (That would be its 28th generation.)

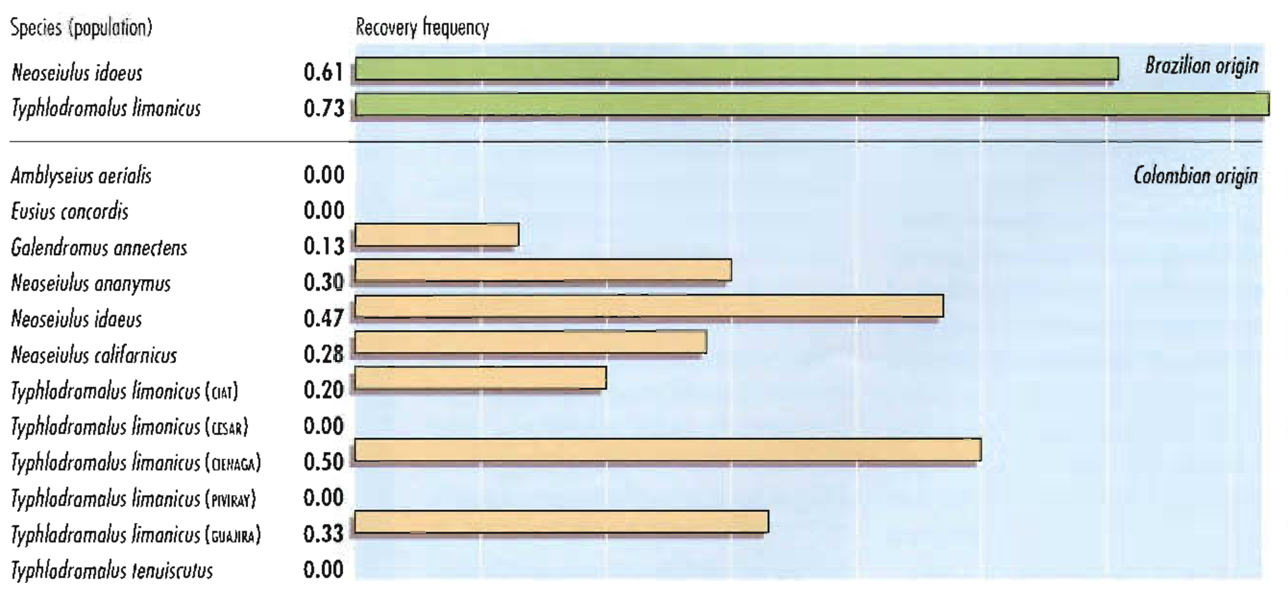
The recovery frequencies for the Colombian phytoseiids were significantly lower and indicate that none was established. The two highest recovery values for populations from Colombia were 0.50 for *T. limonicus* (CIENAGA) in only two fields and 0.47 for *N. idaeus* in more than 50 fields, but never during the wet season. The results for Brazilian and Colombian species and populations are compared in the accompanying chart.

Recoveries from some but not all releases suggest that the different populations of predator mites had different degrees of suitability for specific local conditions. The most important conditions seem to have been availability of alternative prey and sufficient humidity in the predators' microenvironment. The variation in recoveries also reveals that phytoseiids of the same species designation are not necessarily the same ecologically—different populations of the same species do not adapt equally to the same environmental conditions. In this case, the differences between the Colombian and Brazilian populations may warrant distinct species designations.

The first evidence of substantial impact of *T. limonicus* on cassava green mite populations recently came from a release site at Dogbo, Benin, on cassava which had been cropped with maize followed by cassava on poor, sandy soil continuously for 15 years. In this first impact assessment of an experimentally released phytoseiid, the predator had significantly reduced its prey population by 25% after only three months of interaction in the field.

The multi-season and multi-site results are promising for further achievements in the biological control of the cassava green mite. Experimental releases of the Brazilian predators continue. New colonies of these

RESULTS OF CONTINENT-WIDE EXPERIMENTAL RELEASES OF ENEMY MITES IN AFRICA, 1984–1990



exotic phytoseiids are periodically started from field specimens collected in Africa, in order to maintain a well-adapted population base. Other promising species and populations of phytoseiids from different Neotropical locations continue to be imported, to widen the pool of candidates for testing. Frost-tolerant phytoseiids are being identified for eventual release in the cassava-producing highlands of central and southern Africa.

A fungus, too. In a new experimental direction, IITA has begun to pursue a pathogenic fungus found attacking the cassava green mite in Brazil. Selected strains of species of the fungus *Neozygites* will be introduced into Africa during the coming three years in a project to develop another ecologically sound, self-sustaining control for cassava green mite.

During the first year, inoculum will be collected from mite victims of the fungus, for testing on a range of cassava-infesting mites. Suitable species of the fungus will be selected for further research according to their specificity for and virulence on the target prey. Concurrently, development of in-vitro production techniques will enable *Neozygites* to be moved to Africa.

In Benin during the second year of the project, the efficacy of the various species will be determined among mite populations of different densities in different environmental combinations of temperature, humidity, and light. *Neozygites* cultures will be multiplied in preparation for mass production and experimental field releases. Scientists and technicians from collaborating national programs will receive training in insect pathology and field release techniques, to be used later in trials in their own countries. During the third year, the selected *Neozygites* strains will be released in Benin at appropriately timed periods, to determine the optimal climatic, agronomic, and ecological conditions for subsequent on-farm evaluations in other African countries.

A BIOLOGICAL SOLUTION TO THE LOCUST SCOURGE

Swarms of locusts and grasshoppers are among the oldest threats to agriculture in recorded history, from West Africa to China, causing famines and migrations of the affected peoples in search of food. Not until the second half of this century did mankind devise effective means to control massive swarms before they inflict much destruction. These means are, chiefly, systems for early detection of potential outbreaks, and persistent chemical pesticides.

The use of persistent pesticides is, however, no longer an acceptable solution, because of the long-term toxic effects of their residues in the environment. Dieldrin, the most effective chemical for desert locust control, has been banned in all countries where control is needed. Less potent insecticides afford inadequate control and require more frequent applications, hence increase the costs of control and lead to risks of undesirable side effects.

Classical biological control, whereby an exotic natural enemy is introduced into the pest's environment and established for long-term control purposes, has claimed only one success: against the rice grasshopper in Hawaii. Some insect natural enemies can effectively control solitary pest populations—but not locusts in migrating swarms, when they pose their greatest threat to crops. While some of the locust's natural enemies may help terminate such swarms, they do not appear able to prevent them.

One biological possibility holds promise as an environmentally friendly alternative to toxic chemicals—a "biorational" solution to the problem. Microbial pathogens can be manipulated to suit various requirements of large-scale application in place of chemical pesticides. Potentially useful pathogens include viruses, nematodes, protozoa, bacteria, and fungi. Among them, however, only bacteria and fungi can be cultured on the required scale. Of those two, fungi are the most promising—fungi can act as a contact pesticide, which saves steps in a process that must be accomplished quickly in the harsh environment where the pests are to be intercepted. Bacteria, on the other hand, must be ingested by the pest before their action can take effect.

In October 1989 IITA joined the International Institute of Biological Control (IIBC) in the UK in developing innovative biorational means to control locusts and grasshoppers. IIBC had already embarked on key research on the use of a fungus as a biopesticide. Field work was planned to be conducted in Benin, at the IITA Biological Control Center for Africa, and in Niger, with the Département de Formation en Protection des Végétaux. Four donor agencies agreed to contribute to the three-year program: the Canadian International Development Agency (CIDA), Directorate General for Development Cooperation (DGIS) of the Netherlands,

Returning from the fields with a string of locusts for family consumption.

Overseas Development Administration (ODA) of the UK, and the US Agency for International Development (USAID).

Biopesticide. From the outset the project focused on two candidates from the insect-infective group of fungi known as deuteromycetes, which fulfill the requirements of a biopesticide: *Metarhizium* and *Beauveria*. The researchers aimed to find species of those two fungal genera which could:

- be produced cheaply with low-technology facilities in developing countries.
- be dispersed in an appropriate medium by aerial spraying technology for locust control, or by hand-held sprayers for grasshopper control.
- survive the harsh environment where the target pests are found, under high ultraviolet radiation and low relative humidity.
- cause rapid mortality.
- be host-specific, unlike their chemical predecessors, and not threaten other life in the same environment—a vital desideratum in a biopesticide.

In general, research planning adopted a "firefighting" approach—that adult locust swarms are the most viable target for intervention before they reach croplands. Ideally, however, control action should be aimed at newly formed hopper bands before they are able to fly. But the current political situation in the countries where the bands form militates against that approach.

Field work began in Benin during October 1990, with ecological studies. Monthly surveys of pathogens present in grasshoppers in Benin's four southern provinces, and occasional visits in the north, turned up a range of protozoa, nematodes, bacteria, and fungi. Of particular interest have been examples of the fungi *Metarhizium flavoviride* and *Beauveria bassiana*. Others doubtless await discovery, but to date *M. flavoviride* is the most effective as a biopesticide agent. It is highly infectious and can easily be produced on a large scale and formulated for aerial spraying.

Project scientists have investigated *M. flavoviride*, among other fungi, screening them for effectiveness against the desert locust and experimenting with various formulations for controlled droplet application (CDA) at ultra low volume rates. The spores, or conidia, are hydrophobic and thus difficult to disperse in water, but they can easily be suspended in oils. A solution of *M. flavoviride* conidia in oil adheres readily to the pest. The oil protects the conidia from desiccation by the air, and spreads to parts of the body where the fungus can penetrate and do its job of killing its host.

CDA is the application method of choice, for both locust control organizations and farmers, especially where water is scarce. Spinning discs or cages are used to produce a spray of fine, evenly sized droplets, usually of an oil-based liquid such as kerosene which resists evaporation.

The project research team at the IITA center in Benin were able by 1991 to produce a fungal pesticide, or mycopesticide, against the grasshopper *Zonocerus variegatus*, a locally prevalent species which had shown greater resistance to the fungus than others. Conidia of *M. flavoviride* were cultured on rice in plastic bags, then formulated in groundnut oil with kerosene. Tests of the toxicity of the mycopesticide in the laboratory and field yielded overall high mortality among the target grasshopper and other Sahelian species, including the desert locust *Schistocerca gregaria*.

The first field trial took place in the Lama forest in southern Benin, during December 1991, using rotary atomizers to spray the mycopesticide on *Z. variegatus* populations feeding on the ubiquitous weed *Chromolaena odorata*. More than 90% of the grasshoppers collected after spraying had been killed by the applied fungus.

The project hosted a workshop on the biological control of locusts and grasshoppers in April 1991, attended by over 90 scientists from Africa and elsewhere. The proceedings have been published by CAB International in English and French. In order to introduce the use of the mycopesticide to African scientists, a series of annual training courses is planned, starting in 1992.

Research in the second half of the project will include:

- further ecological studies on grasshoppers and pathogens
- development of mycopesticide production facilities in collaborating countries
- field trials on Sahelian grasshoppers and locusts

Spraying of the fungal conidia suspended in kerosene.

- environmental impact studies.

Impact. While the research team expects no significant environmental hazards as a result of future spraying campaigns, the risks of mycopesticide use must nonetheless be assessed beforehand. The foremost concern is the hazard to life forms with valuable ecological roles: the insects, reptiles, birds, and other creatures which serve as pollinators, natural enemies of pests, or benefactors in other ways.

Experience in assessing environmental risks with mycopesticides is limited, but the pathogens involved are not known to cause environmental problems where they occur naturally. No fungal infections have been reported to have spread from locusts or grasshoppers to other organisms. Moreover, the environmental load of infective fungi from spraying may be less than that of natural epidemics. The strategy for risk assessment for the mycopesticide will be to define the potentially significant areas of risk, to eliminate the irrelevant ones, and to address the remaining risks with existing testing and evaluating procedures.

The focus of research will be consumption of infected locusts and grasshoppers by birds and other vertebrates, and effects on beneficial insects or others which may multiply in future in the absence of control by locusts or grasshoppers. No adverse effects on people are anticipated, in light of experience of these fungal pathogens and experience with earlier use. Potentially nauseating effects of the solvents used in producing and applying the fungi are to be minimized and carefully monitored.

Apart from these mycopesticides, the biological alternatives to chemical pesticides being researched all take several days to kill their hosts. This solution will work where the pests are not in immediate threat to crops. With the development of early warning networks at the locusts' origins, outbreaks can in future be detected in time to enable treatment with environmentally safe biopesticides, far from the croplands we seek to protect.

Biorational. While classical biological control remains the method of choice in crop protection, that approach will not always suit the nature of the problem nor yield good results. A biorational means of control provides one alternative, entailing use of a plant extract, a pathogen, or an insect. The biorational researcher will need to do more work in preparing a campaign than in organizing a biological control project, and much more work than for a chemical pesticide operation. However, the gains should more than repay the extra effort. With much-reduced environmental damage and no hard currency costs, these agents ought to be welcomed as a new technology to relieve African agriculture of an ancient scourge.

RESEARCH TO DEFEAT THE STRIGA THREAT

Professor S. N. C. Okonkwo of the University of Nigeria at Nsukka, an authority on the biology of **Striga*****, is investigating why nitrogen fertilizers are observed to reduce*** **Striga** ***attack in the field. Among Professor Okonkwo's contributions from more than 20 years of*** **Striga** ***research are tissue culture systems that enable the parasite to be grown apart from a host—an essential technique in tackling the complex problem of this pest. In 1991, during a year's sabbatical leave at IITA, he began in-vitro studies to assess the effects of nitrogen on*** **Striga** ***in the absence of a host.***

Early findings from the studies indicate that nitrogen does directly inhibit **Striga** ***growth. Confirmation of these results could lead to development of some form of nitrogen as another option for control of the parasitic "witchweed". Such a solution would be welcomed as cheaper and less environmentally disruptive than most herbicides.***

In the following paragraphs, Professor Okonkwo provides some insights into the complexities of the problem, and how current research is approaching several prospective solutions. The problem in the West African savanna is described in subsequent pages, together with the IITA program to defeat the **Striga** ***threat.***

Prof. Okonkwo (right) with Dr. Nkem of National Cereals Research Institute, Nigeria.

What is Striga*? What does it do to a farm, and how does it threaten agriculture in Africa?*

Professor Okonkwo: *Striga* is a parasitic flowering plant which inhabits savanna grasslands over much of Africa. Being a green plant, with a shoot and roots, it is sometimes called a "parasitic weed". You would not realize it was parasitic unless you dug it up and saw how its roots were attached to the roots of its host plant. Of greatest concern to us are those *Striga* species which evolved a parasitic relationship with monocots, or grain-bearing plants with leaves having parallel veins—cereals in particular. Other important *Striga* species formed evolutionary "attachments", so to speak, for broad-leaved plants—such as for cowpea, or in Ethiopia and East Africa, for tobacco.

Being a parasite, *Striga* diverts its host's nutrients to itself—in most cases so efficiently that its effect on its host is highly debilitating. Farmers can experience losses in their grain yields of about one-third, up to their entire crop, depending on the extent of the infestation. The threat to African agriculture is therefore tremendous. It is especially grave in the moist savanna of Nigeria and other parts of West Africa, where maize is supplanting other grain crops, the traditional staples of sorghum and millet. Maize is much more susceptible to *Striga* than they are.

Maize is a "New World" crop which has not yet adapted to *Striga* the way the indigenous grain crops have. Some sorghum and millet lines have developed a degree of tolerance or immunity to *Striga*, and farmers have managed to live with the level of damage that it does to those crops. Maize, however, is attracting farmers because it can produce higher yields than the other grains, when given the right amounts of fertilizer and other inputs. And maize is such a versatile commodity, it has many uses and brings good incomes to farmers who have access to the right markets. So, many farmers in the moist savanna who can obtain the fertilizer and seeds are switching to maize. The expansion of a susceptible new host in a relatively brief time greatly increases the potential for *Striga* to expand.

A crucial aspect to the threat lies in the nature of *Striga* reproduction. First of all, *Striga* seeds are microscopically small—the longest one ever measured, I believe, was half a millimeter. A *Striga* plant produces thousands of them each season. They lie on or under the soil surface and will not germinate, until they come into contact with a chemical exuded by the roots of a suitable host plant next to them. The newly germinated *Striga* produces rootlets, which are able to dissolve the walls of the host plant's roots and penetrate to the conducting tissues. These become the food source for the growing parasite. So one part of the problem is the longevity of so many tiny seeds, which can remain dormant for many years and still be able to germinate. The other part is the devastating nature of the relationship between the parasite and its host.

Do you see any possibility of a research breakthrough that could help stop this menace?

Professor Okonkwo: Research to conquer the threat should take a number of approaches in order to yield a solution, or combination of solutions. It would be wrong, and unscientific, to rely on a single means such as resistance breeding to provide a solution by itself. To succeed in an attack against an enemy, you should learn as much as you can about your enemy's resources before you decide on your strategy and launch an attack.

The biology of the *Striga* plant is part of the essential research, along with the interactions between parasite and host plant. Field studies of *Striga* effects on crop yields are also very important, to assess yield losses and cultural practices which can reduce them.

We need to know much more than we do about the way the *Striga* plant functions. Even the chemistry of germination is not yet fully understood—it was only in 1972 that we were able to characterize the main reaction that stimulates germination. If we can replicate this stimulus, we can trick the *Striga* into germinating in the absence of a host. Without a host for its food supply, it must die, for the seed stores only enough food to carry the rootlet through its attachment to a host. If we can in this manner reduce the *Striga* seedbank in the soil, fewer plants will emerge during the following season and the host crop will fare much better.

Among the areas in an integrated approach which should yield an early breakthrough, judging from the current state of progress, is breeding of resistance to *Striga* in the host crop of maize. Resistance breeding could provide a most economical and practicable control measure, and its benefits could be extended on a large scale.

Another important area, which interests me personally, is the use of nitrogen fertilizer as a *Striga* suppressant. The effect of nitrogen applications in farmers' fields, in reducing the emergence of *Striga*, has been observed for some years, but we don't really know yet what we are seeing—are we strengthening the host plant, which in turn becomes better equipped to resist *Striga*? Or does the nitrogen act directly to suppress *Striga*? Nitrogen applications could be another practicable control measure, provided the recommended levels of nitrogen were not too expensive, nor great enough to pollute the environment. They would have the double advantage of increasing crop productivity, while inhibiting *Striga* at the same time. We are developing an in-vitro system for assessing the effects of varied levels of nitrogen on *Striga*.

THE STRIGA PROBLEM IN THE WEST AFRICAN SAVANNA, AND IITA'S PROGRAM TACTICS

The phenomenal spread of maize farming in the West African savanna since the 1980s carries the threat of its own destruction, in the form of the parasitic "witchweed", *Striga*. Improved maize has brought new income to farmers, but—as an exotic crop—is highly susceptible to several species of *Striga*, a parasitic weed that has coevolved in Africa's savanna lands with indigenous cereals and legumes. *Striga* saps the vigor of its victim crop, decimating harvests and sometimes forcing farmers to abandon their fields.

In recent decades population pressure has forced farmers to work the land ever more intensively, to keep their farms viable and feed increasing numbers of people. Fortuitously, the right circumstances had materialized by the 1980s to enable farmers to begin modernizing their agriculture: appropriate technologies as inputs, an agricultural extension system, growing urban and industrial markets, and road networks for transportation to those markets.

The right crop for this ripe economic situation was an improved maize, developed by IITA scientists during the 1970s—high-yielding, resistant to the major diseases, and highly adapted to growing conditions in the moist savanna. Farmers have adopted maize increasingly each year over the past decade, partly in place of the traditionally cultivated sorghum and other crops.

Intensified farming of a single crop has upset an age-old agroecological balance. Lengthy fallow periods and a diversity of crops used to restrict pests, including *Striga* species, to a moderate presence and level of damage. Intensification has reduced or eliminated the fallows, along with their benefits of restoring soil fertility and maintaining a seedbank of competing flora. The combination of reduced diversity, declining fertility, and a particularly susceptible crop have opened the environmental doors to *Striga* proliferation.

The *Striga* threat can be measured by the extent of cultivation of susceptible cereals and legumes. In the Nigerian moist savanna, for example, sorghum is grown on approximately 5 million hectares, millet on 4 million, and maize on 2 million. Cowpea is intercropped with all of those cereals. Different species of *Striga* are estimated to have infested 40% of all fields of those crops in the moist savanna by the end of the 1980s. *Striga* also parasitizes other crops such as upland rice, "hungry rice" (*Digitaria*), and sugarcane.

Strategy and tactics. Early in the 1980s IITA scientists began to combat the problem, initially through breeding of improved maize varieties resistant to *Striga* parasitism, and later through other biological and agronomic research. In 1989 IITA decided to combine the diverse efforts in a concerted thrust. By 1991 a multidisciplinary group had grown to encompass 12 scientists working in related approaches toward a common understanding of (a) what settings and conditions are most propitious for different *Striga* species, and (b) what control measures are most effective against those species in such environments. These scientists coordinate research activities with national programs throughout Africa and with universities and research institutes in many parts of the world.

IITA's *Striga* research group focuses on the following areas of activity:

- Biology of *Striga* species
- Epidemiology and population dynamics
- Host plant resistance
- Agronomic and cultural management
- Biological control
- Socioeconomic studies
- Training and technology transfer.

Scientists from many disciplines compose the *Striga* group, which is based in IITA's Plant Health Management Division. Other scientists in the various IITA programs for crop improvement and resource and crop management collaborate in *Striga*-related socioeconomic studies, agronomic and cultural management, and training and technology transfer activities.

***Striga* biology.** Several *Striga* species indigenous to West Africa cause yield loss in maize and other cereal crops to varying degree: *S. hermonthica*, *S. asiatica*, *S. aspera*, and *S. forbesii*. Cowpea is susceptible to *S. gesnerioides*.

Infestations of these parasitic weeds depend on timely germination of their seed. Control methodologies might be developed by manipulating the dynamics of seed dormancy and germination. Researchers have succeeded in artificially stimulating the seed to germinate. The *Striga* germling dies if it does not encounter a root of a potential host within a few millimeters in the ambient soil. Similarly, certain plant species which are not *Striga* hosts can stimulate its seed to germinate, whereupon the germling dies for lack of a suitable victim.

Such "trap" crops could provide an economical means of control. Some have been selected and, together with low-cost materials for implementing the strategy, are being put in on-farm trial packages.

An alternative strategy would be to protect the host from attack by inhibiting *Striga* germination. A protectant for the host seed could turn out to be another economical type of control measure, so development of this possibility has begun.

A seed elutriation or separation facility was set up at IITA during 1991 to isolate and count *Striga* seed in a given amount of soil, before and after different experimental treatments. *Striga* seed is especially difficult to examine, since each seed weighs an average of 5 millionth of a gram. Several legumes were evaluated together with maize for their combined effect in reducing the *Striga* seedbank in the soil, in comparison with fallowing. Soybean and a fodder legume (*Aeschynomene histrix*) were found to reduce *S. hermonthica* seed levels in the soil.

Epidemiology and population dynamics. The occurrence of *Striga* species in time and place, and their interactions with hosts and other plants and organisms, occupies much of the *Striga* research group's effort. In general, *Striga* species occur in economically significant populations in the savanna areas in West and Central Africa, and in the eastern and southern African highlands.

In West Africa, all *Striga* species do not, however, occupy the same agroecological habitats. The southern extent of *S. hermonthica* is the moist savanna, while *S. asiatica* extends even farther south, into the forest

When *Striga* strikes some fields, farmers must abandon their crops.

margins. *S. gesnerioides* occurs in different forms—each has an affinity for a specific host plant, and so has a specific habitat. The niches for the less well-known species such as *S. aspera* and *S. forbesii* appear to be even more restrictive. The governing mechanisms of those distributions are still poorly understood. Eventually the explanations will be useful in designing control schemes.

An "expert system" is being developed with three interlinked models. One of the models has been designed to orient research on the population dynamics of the various *Striga* species. Another will relate the growth of different *Striga* populations to decline in maize growth and crop production. The third links yield performance with adoptability of *Striga*-specific technologies. (See paragraph on "Socioeconomic studies".)

Host plant resistance. Mechanisms of resistance and its genetic sources have been studied because resistant crop varieties are promising economical technologies to add in control packages. The group has developed a method of *Striga* infestation for screenhouse and field use which yields consistent infestations in resistance breeding trials. The method was put to use in field studies of yield losses in maize under different infestation levels. On-farm trials investigated how *Striga*-tolerant maize varieties suppressed *Striga* damage in farmers' fields. The *Striga*-tolerant lines showed significantly greater yields under *Striga* pressure than non-tolerant lines, while only slightly reducing *Striga* emergence. Farmers' reactions to the IITA materials have been favorable.

Agronomic and cultural practices. The IITA group developed a survey methodology to analyze the impact of *Striga* species in the farming system and estimate crop yield loss. Research characterized *Striga* environments with analyses of crop choices, cropping patterns, prevalence of sorghum, and production systems.

Striga environments on farms in the northern moist savanna in Nigeria have been intensively studied over the past three years, collaboratively with the Institute of Agricultural Research, Samaru. A general objective is to study the impact of changing production systems, particularly intensified maize farming, on the different *Striga* species.

During 1991, data from that exercise were analyzed to determine (a) whether some farming systems were less prone than others to develop *Striga* problems, and (b) what control strategies would be appropriate. Field results show that cereal cropping with a high proportion of sorghum is the most affected by *Striga* of all systems, because *Striga* produces seeds when sorghum is its host. A combination of factors seems to militate against *Striga* reproduction with a maize host plant under farm conditions. Hence, under the right kinds of farmer management, intensified farming of maize without sorghum may even reduce *Striga* infestation levels.

Other research during 1991 showed that intercropping of cowpea or soybean with maize reduced *Striga* emergence significantly, in comparison with monocropping of maize. Applications of the herbicide dicamba together with nitrogen fertilizer significantly reduced *Striga* emergence, flowering, and seed production, which resulted in an increased maize yield. A parallel experiment with dicamba which involved traditional weed control practices of remoulding, or heaping soil onto the planted ridges, also inhibited the emergence of *Striga* and yielded maize crop increases. However, the same treatments with sorghum did not significantly reduce *Striga* emergence.

Biological control. Biotic elements of the *Striga*-maize system at Mokwa in Nigeria are being studied, on the evidence of *Striga*-suppressive conditions documented there since 1984. Preliminary research has identified possible biological agents and quantified their impact in farmers' fields. Potential pathogenic agents have been isolated and are being studied. In neighboring Benin, a 1991 survey revealed some biotic factors which influence *Striga* fecundity throughout the country. *Striga* growth appears to have "plateaued" or started to decline in some areas of Benin.

Socioeconomic studies. The *Striga* research group has developed a model which will predict the adoptability of different control measures with respect to their impact on yield and the cost of their implementation. The model is part of an "expert system" designed to predict the efficacy of those measures in controlling population growth or decline among different *Striga* species. The adoptability model will help the group to determine the cost-effectiveness of the entire research progam.

Technology transfer. Training programs in conducting research on the various *Striga* species and subspecies, susceptible crop varieties, and cropping systems have been implemented at national facilities in Burkina Faso, Cameroon, Côte d'Ivoire, Nigeria, and Togo, as well as at IITA. The Pan-African *Striga* Control Network (PASCON; an information network funded by the Food and Agriculture Organization of the United Nations) has proposed to expand the training to 12 additional countries. The IITA group has begun to prepare a manual on *Striga*-maize research methodology for this program.

During 1991 the group also extended its method of spot infestation to collaborating programs in Cameroon, Ghana, Nigeria, and Togo.

Supplementary strategies. Current control strategies rely on resistant crop varieties, trap crops, and agronomic practices such as crop rotations and weeding. The IITA *Striga* research group is also developing germination stimulators and inhibitors, and methodologies for biological control. The group is devising a decision-making strategy which links different packages of control measures with different *Striga* population dynamics and socioeconomic conditions. The aim is to create a capability to tailor control packages to local conditions and individual farmer needs. The group hopes to see substantial results of its research translated into practicable technologies at work in farmers' fields within the coming three years.

RESOURCE AND CROP MANAGEMENT

The Resource and Crop Management Division conducts research on the physical and social dimensions of the farming environment and on technologies which improve farm productivity on a sustainable basis, in collaboration with national programs in sub-Saharan African countries.

RESEARCH DIRECTIONS

RESOURCE MANAGEMENT

- Description, measurement, classification, and mapping of the biological, physical, chemical, and socioeconomic characteristics of the IITA mandate area.
- Quantification of fundamental relationships among factors contributing to the sustainability of food production systems. Process studies (for example, biological regulation of nutrient cycling physical factors affecting soil fertility, factors regulating interplant competition) to continue on nonacidic and acidic soils, including the low-phosphate acid soils, at the new Humid Forest Station at Mbalmayo, Cameroon.
- Development of indices for measuring the sustainability of small-scale cropping.
- Development of multipurpose agroforestry systems which combine improved soil and weed management.
- Development of economically viable and sustainable fallow management systems incorporating herbaceous legumes.
- Assessment of agricultural sustainability under traditional and improved resource management methods.
- On-farm testing and validation of new technologies, emphasizing alley farming under different socioeconomic conditions.
- Development of system simulation models, emphasizing intercropping, nutrient cycling in alley farming systems, and economics/ecology of inland valleys.

HUMID FOREST SYSTEMS

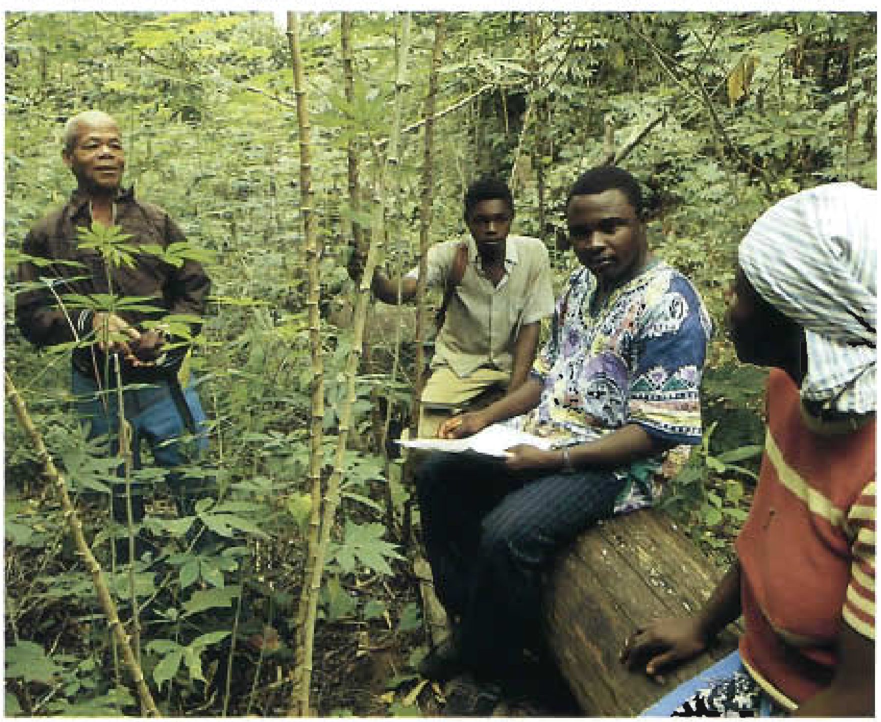
- Investigations of resource use and productivity problems in cassava-based intercropping systems.
- Investigation of the adoption and impact of improved cassava varieties.
- Collaboration with national institutes, to improve cassava intercropping in alley farming systems.

SAVANNA SYSTEMS

- Characterization and classification of maize-based farming systems in the moist savanna.
- Investigation of effects of intensified maize farming on *Striga* infestation.
- Development and testing of cultural methods for control of *Striga* and improvement of soil fertility.

INLAND VALLEY SYSTEMS

- Characterization and classification of inland valleys in West and Central Africa.
- Development of models of environmental and socioeconomic processes in inland valley agroecological systems.
- Design of technologies or interventions to improve land use and management practices.



The Collaborative Study of Cassava in Africa is investigating cassava production impacts and problems in 14 sub-Saharan countries.

UNDERSTANDING THE LIMITS OF THE FARMER'S ENVIRONMENT

AGROCLIMATOLOGY AT IITA

In meeting the challenges of Africa's rapidly growing food needs, one indispensable tool is a knowledge of the natural environment and the uses of its resources. The characteristics of the environment, its capacities and limitations, determine potential agricultural production. Armed with an understanding of the physical limits of the agricultural setting, researchers can develop suitable resource and crop technologies which can help farmers realize the most from their efforts.

IITA's resource and crop management strategies are based on such an understanding of the agroecological environment and the elements governing production. The approach begins with compiling a range of information about environmental characteristics, farming systems, and a range of socioeconomic indicators.

Interdisciplinary groups of scientists use this information in developing crop varieties and farming practices to suit the environment which can increase farmers' productivity, but which do not compromise the production potential for posterity. The goal is to replace production methods which degrade the resource base with methods that are environmentally sustainable.

Data bases relevant to Africa on climate, soils, vegetation including forest cover and crops, topography, population, and other socioeconomic and farming systems-related information were compiled at IITA during 1990 and 1991, with help from the Centro Internacional de Agricultura Tropical (CIAT), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Environment Programme (UNEP).

Historical daily weather data were obtained for several African countries, for use in determining the extent of climatic change during the past 30 years. Preliminary analysis reveals that rainfall has decreased in both amount and duration.

Year-to-year variations in the weather have a widespread environmental impact which results in great variations in crop yields. Hence, weather is the main risk to be taken into account in agricultural decision-making. In the analysis of weather impact on agriculture, and in many applications related to soil management, water control, and crop management, many years of daily data on rainfall, maximum and minimum temperatures, solar radiation, and potential evapotranspiration (the amount of water needed to sustain vegetation in a particular area) are required.

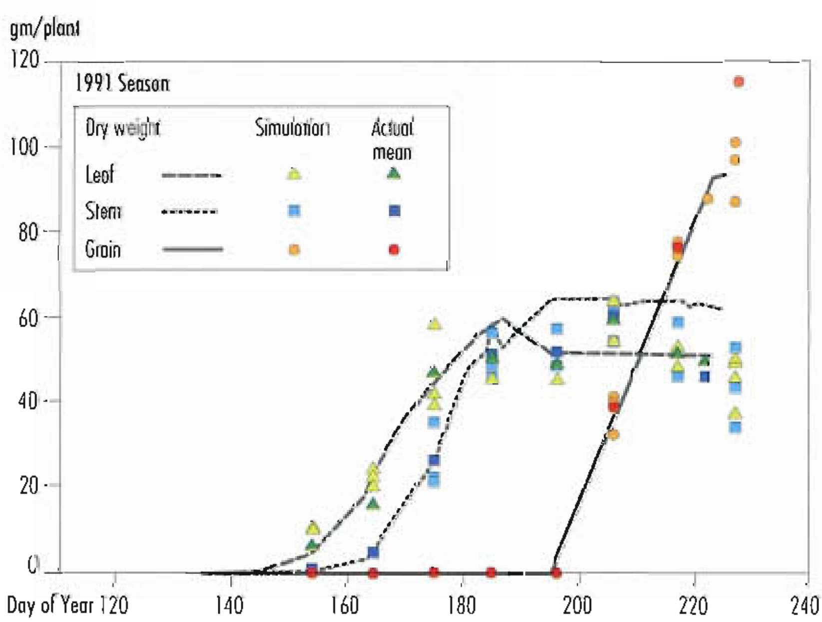
Since daily data are not available for many African countries over sufficient time periods, IITA has developed "weather estimators"—computer-based models which simulate a series of daily values for rainfall, maximum and minimum temperatures, solar radiation, and potential evapotranspiration for specific areas, based on existing historical weather data using a set of location-specific limits. A weather "history" for the whole of Nigeria has, for example, been estimated during the past two years in this manner.

The collection of actual and simulated data has enabled IITA and CIAT researchers to jointly develop continent-wide grids for Africa and South America with an information series for every 100 square miles of land area. With primary information about rainfall and soil resources, scientists can estimate the waterholding capacity of the land and hence the length of the growing period for rainfed agriculture in that location. Water-based transport also depends on rainfall. A variety of crop management applications is possible with the use of such information.

Using simulated daily data on agroecological conditions, a crop model can overcome the lack of actual data to serve research purposes where no historical series exists. A model which simulates crop yields under various conditions, including weather and farmer inputs, can help in assessing the risks and determining management options in producing a given crop in a particular location.

IITA tested such a model to simulate maize production during the 1990 and 1991 growing seasons in Ibadan, an area characteristic of the forest-savanna transition zone in southwestern Nigeria. The model, developed by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) at the University of Hawaii, was designed to predict physiological processes of plant growth and crop yield over daily time periods, simulating the processes as they are thought to occur in the real plant.

CALCULATION OF LEAF, STEM AND GRAIN DEVELOPMENT



Two consecutive years of field observations of a sole crop of maize showed excellent agreement between simulations and actual above-ground development of the biomass, in terms of the dry weights of stem, leaf, and grain of the maize throughout the two seasons. The accompanying table shows how the simulated calculations of leaf, stem, and grain development over the 1991 cropping season fall almost perfectly within the means of actual performance.

Resource information system. During its 25-year history IITA has accumulated substantial records on soils, crops, diseases, pests, farming systems, and economic factors which characterize various parts of sub-Saharan Africa. IITA's newly developed resource information system (RIS) has begun to make these data accessible by personal computer.

RIS provides a wide range of geographic information on specific areas which traditionally would have required use of maps and compendiums of data. Given a set of longitudinal and latitudinal coordinates, it can provide a variety of information on that specific location.

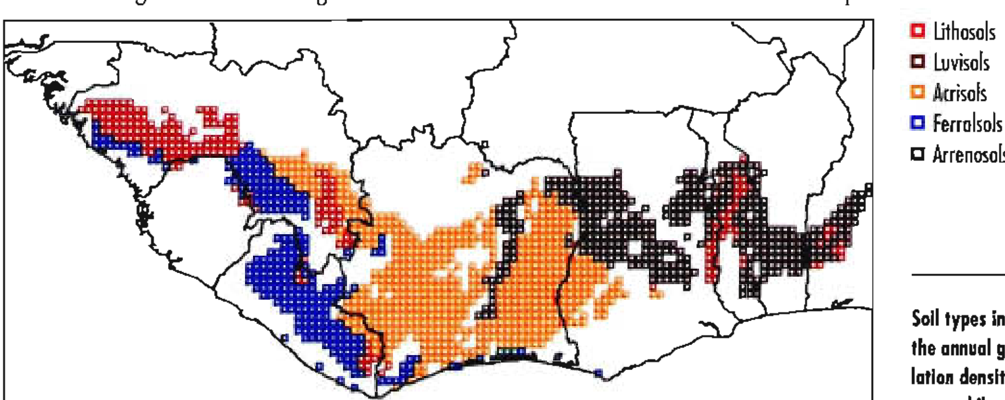
For basic research uses throughout its mandate area, IITA has begun to establish a minimum data set for access through the RIS. The minimum data set comprises climatic variables, terrain and substrate variables, production systems, and socioeconomic variables.

Besides information storage and retrieval, RIS can analyze spatial and descriptive data and establish spatial relations among them. Researchers have used it to examine links between specific rainfall and temperature conditions and the incidence of pests. For example, in the search for a natural enemy of the cassava green mite for biological control purposes (see article "The search for the right mite" on pages 21–24 of this report), the ecological equivalent of the mite's African habitat was located in South America, where predators of the mite were subsequently discovered. The validity of the technique was confirmed after the predators had been imported and became established in selected areas of West and East Africa which matched their areas of origin.

Some of the more frequent RIS applications include selection of survey sites, delineation of agroecological zones, identification of suitable environments for crops with specific characteristics, and ecogeographic studies to guide germplasm exploration and preservation. Survey results can be linked with basic biophysical data (such as climate and soil) and socioeconomic data (such as population and income) in drawing out conclusions for policy action, as illustrated in the following example.

The accompanying map of coastal West Africa characterizes the regional environment for inland valley agroecosystems. The dots represent units of 100 square miles each, colored according to soil type which can indicate suitability for various kinds of crops. The soil types have been indicated only for those areas which have other specific characteristics—in terms of climate, population density, and per capita income—that fall within the planning targets of agricultural policymakers. This information can help in the estimation of the food production potential of inland valleys and in decision-making on land use and management.

RIS provides an integrated base of wide-ranging data which facilitates analysis of resources, cropping systems, population, livestock, pests and pathogens, and many other variables in IITA's mandate areas. Rapid availability of useful information is helping to focus development of new technologies more precisely to suit specific needs among IITA's national partners in agricultural research.



Soil types in selected West African countries where the annual growing season is 7 months and the population density is equal to or less than 30 people per square kilometer.

ON-FARM RESEARCH GOALS ATTAINED

NIGERIAN SCIENTISTS TAKE OVER VILLAGE SITE

On-farm testing of technologies is as old as agricultural research itself, but only recently has it become widely accepted as an essential step for research institutes to take in the search for adoptable technologies. IITA's commitment to on-farm research, and to the principles of farming systems research ingrained in it, has been extended to collaborative activities with national programs. (See article on research collaboration in the International Cooperation section of this report.) A significant instance of this occurred during 1991 in the transfer of responsibility for on-farm research facilities, jointly developed in southern Nigeria, to the University of Ibadan.

The farming systems approach to agricultural research was evolved during the 1970s and 1980s partly because research results were not, in tropical countries, reaching the farmers. Farming systems research directed scientific attention at the farm setting, and its various constituent elements, which could help or impede the small farmer in applying new technologies to overcome production constraints.

IITA scientists contributed to development of farming systems concepts and methodologies, with characterization of the farmer's resource base and diagnosis of farming constraints. The IITA farming systems program researched prototype technologies, with the aim of making them available to national agencies to modify and adapt to the specific conditions prevailing in their countries.

Early in the 1980s IITA began conducting on-farm research in several locations, to test new technologies and improved methodologies under the real conditions for which they had been designed. Research sites and working relations with farmers were built up from 1986 at Ayepe, a village in Osun State (formerly part of Oyo State) in southern Nigeria. A field house was constructed with space for an office, a simple laboratory, and accommodation for temporary stays for up to eight researchers, field staff, and students. A generator, a drinking-water well, small motorcycles, and other amenities were provided. Site development was financed by the Ford Foundation as a means to support IITA in building up a collaborative program in on-farm research with national agricultural research institutions.

From the outset, IITA developed the site jointly with the departments of agronomy, agricultural economics, and agricultural extension of the University of Ibadan. The University had been among the first national institutions in Africa to adopt farming systems research concepts, and had conducted innovative research in intercropping from early in the 1970s. The Ayepe site provided the University with a training facility for its students, many of whom conducted their thesis research there under the joint supervision of University and IITA scientists.

The intention from the beginning had been that the Ayepe facilities would eventually be transferred to the University of Ibadan. The transfer took place during the course of 1991, in fulfillment of the founders' plans.

Responsibility for the site passes to two committees, on policy and on research, and to a site supervisor for operations and research from the University's agronomy department. The policy committee is composed of the heads of the participating University departments, the director of IITA's resource and crop management division, and a representative of the Ministry of

Student researcher from University of Ibadan seeks Ayepe farmer's opinion.

Quantifying the results of an Ayepe on-farm experiment.

Agriculture and Natural Resources. The research committee is composed of scientists actively involved in field work at the site.

Ayepe will thus continue to provide the setting for training of University students under real farm conditions. It is likely also to develop into a major tool in the advancement of farming systems research among Nigerian institutions, through the National Farming Systems Research Network. The site is expected to become a training facility for teams from network member institutes. Funding for the site continues to come from the Ford Foundation, which also supports the network, so sponsorship for the enlargement of Ayepe's role is already in place.

Roles in the system. In the established system for on-farm research, the role of an international agricultural research institute is to develop new materials and prototype farming practices, which are further refined, tested, and adapted by national agricultural research institutions. Extension services and development organizations usually help to carry the testing and demonstration further in each particular country.

In this process, on-farm research is part of every national research system's function of adapting such technologies for utilization under local conditions. Every research institute in Africa should have its own on-farm research capability, closely tied with extension agencies and, if possible, an institution of higher learning. In Nigeria, several such mixed teams already cooperate with state agricultural development projects in conducting on-farm adaptive research.

Prototype innovations cannot, however, be effectively developed without some exposure to farming conditions. Scientists in the international centers need direct contact with African farmers to observe farmers' constraints and problems. They need a field laboratory to test how realistic their ideas are—whether their technologies offer any real advantage over what farmers are already doing or using. On-farm testing can thus help avoid the costly mistake of pushing new technology to the farm which farmers perceive as not being useful.

Moreover, national institutes create a strong demand for training in on-farm research techniques. International centers cannot possibly respond to such training demands unless they have firsthand experience on the farm.

Early in the 1980s, therefore, IITA began to become increasingly involved in research in farmers' fields and in the training of African scientists in on-farm research methods.

The procedures for on-farm research are not rigid, and methodology is adapted to the researcher's own resources, capabilities, and available disciplines.

Main actors. The essential features of such a research enterprise are the interrelations among the main actors: research institute, extension service, and farmer.

- The institute must conduct its on-farm research in close cooperation with extension or development agencies. Since they are in the best position to disseminate the final resultant technology to farmers, they should be intimately involved in the on-farm testing process. Early collaboration can prevent friction that could arise between the two if extension personnel feel that researchers are intruding on their territory.
- The most relevant results will come out of maximal farmer involvement in the trials. The researchers should find farmers who are genuinely interested in testing the new technologies in their own fields. If the participating farmers are simply making their land available for researchers to conduct trials, the research will amount to little more than on-station trials in farmers' fields.

Late in 1985, the year before Ayepe was developed as a research site, scientists from IITA and the departments of agronomy, agricultural extension and agricultural economics at the University of Ibadan, together with Ministry of Agriculture and Natural Resources officers, conducted an informal "diagnostic" survey of farming systems in the area. The group developed preliminary hypotheses about the main production constraints, and held village meetings with farmers to discuss options for field research and interventions.

Over the years the work at Ayepe covered a wide range of topics, including socioeconomic and agronomic characterization, studies of soils, vegetation, and crop pests, testing of new or improved crop varieties, fertilizer and weed control practices, alley cropping technologies, and modelling studies to quantify production constraints.

The researchers maintained a high level of farmer involvement in the work. Farmers participated in design and management of trials to a maximal extent. They met regularly with the researchers and extension officers in each case to evaluate results and plan further activities.

University students and their supervisors participated in all aspects of the research at Ayepe. The evolving activity at the site advanced farming systems research as a discipline in Nigerian universities. The participating universities, the agriculture and natural resources ministry, and IITA formed a joint research committee to review all research activities. The committee assessed and approved Ford Foundation grants made available to students in support of MSC and PhD thesis work. Ayepe has been the field site for research for a total of 14 MSC theses and 15 PhD theses from 1985 through 1991.

Adoption. Among the events marking the transfer of Ayepe custodianship was a symposium, where the strengths and shortcomings of previous work were reviewed. A major concern was the low adoption rate of several of the technologies tested in this on-farm "laboratory". The same complaint is heard in many other areas as well, and is one which agricultural research in Africa must address.

The most successful technology has turned out to be an improved cassava variety, TMS 30572, which is now widely grown in Ayepe as a result of tests in farmers' fields. Its superiority in yield is conspicuous, while multiplication by the farmers themselves poses no problems.

Adoption of improved maize and fertilizer has been very modest in Ayepe, mainly because supplies of inputs have not been readily available. Soybean, introduced as a crop for household consumption, has found a small niche, but adoption is not widespread. A vigorous effort seems to be needed to promote soybeans in the local diet as an alternative or in addition to cowpeas.

The Ayepe verdict on alley cropping is not yet out, but farmers appear not to have found it sufficiently attractive—in combination with the staple food crops of maize and cassava—to justify the extra labor inputs. Most of the farmers had originally interplanted hedgerows in their alley cropping trials with improved oil palms at a low density, as a "carrier crop" to provide some tangible return. Significantly, after harvesting the food crops, several of them continued to prune the hedgrows adjacent to the oil palms while letting the rest of the field revert to fallow. They appear to consider the oil palm more important than the hedgerows.

The low rate of technology adoption at Ayepe might possibly be explained by:

- Innovations which are not as good as researchers like to imagine.
- Extension and input delivery systems which are ineffective.

Above all, the innovation must be something worth adopting. If farmers see no value in a new variety or farming practice, nothing can persuade them to adopt it. Researchers and extension workers must be able to identify a worthwhile innovation or idea to develop, in a systematic testing effort which can expose its shortcomings. That is what on-farm research is all about.

Extension services must be both strong and effective. In many areas they are insufficient, or even completely lacking. The farmers there may never be exposed to the advantages of new varieties, fertilizer use, or new soil management practices. In other areas, massive extension schemes have been installed with inputs delivering systems, but have not made desired impact in agricultural production. Effectiveness can, therefore, be as elusive a characteristic of extension systems as it is of the innovations themselves — and just as essential.

New round. Thinking about new opportunities keeps evolving, and IITA continues to collaborate with scientists and students from the University of Ibadan in this process. Ayepe researchers may not as yet have identified really attractive technologies, suitable for the area, but they are reconsidering their assumptions and designing a new round of experimentation in consultation with the farmers.

The 1991 symposium concluded that researchers should concentrate their interventions on crops and cropping techniques with highest potential in the area. Those would include oil palms, yam (not tested in earlier trials), and possibly soybeans.

Village meetings were held during 1991 to gather farmers' views on possible interventions. The farmers confirmed their interest in such crops as plantains, oil palms, and yam. Farmer participation will be further strengthened with the formation of "interest groups" around specific technologies.

Since the symposium, researchers have hypothesized as well that alley cropping may have potential in the area, where pressure on the land remains moderate, if it allows production of a high-value crop which cannot be grown profitably otherwise. One such crop is plantain or banana. Trials with improved materials, resistant to black sigatoka disease, will begin in an alley cropping scheme during 1993.

MUCUNA

FARMERS TURN EXPERIMENTERS WITH A DUAL-PURPOSE TECHNOLOGY

Mucuna has become a byword in the Republic of Benin among farmers and agricultural extension workers, as an example of a soil management technology that is solving a major weed problem as well as helping to restore soil fertility.

It all began in 1986, when IITA and Beninois scientists started on-farm research in Benin on methods to restore soil fertility and—at the same time—to encourage farmers to participate in the experimentation process, as a means to develop practical, adoptable technologies. One such technology, the cultivation of a ground cover or live mulch, *Mucuna pruriens* var. *utilis*, enriches the soil with nitrogen. As mucuna spreads over the ground, it also has the welcome effect of smothering young shoots of "speargrass", the noxious weed *Imperata cylindrica*, which has widely infested the impoverished soils of the region.

The popularity of mucuna has led to its adoption by the national extension agency for countrywide application, and to selection by the Global 2000 project for demonstration trials by 500 Beninois farmers. This success is due in large part to the enthusiastic efforts of the participating farmers to develop the technology.

Farmers accepted mucuna after seeing how effective it was in combating two of their main farming problems: restoring soil fertility so that maize yields improved, and halting the rampant speargrass by covering the ground and preventing the weed from receiving adequate sunlight. The farmers' contributions over four years of mucuna research gave them a stake in the results, motivating them to encourage others to use it as a result of their experience.

Evolving project. Concern about declining soil fertility led IITA, early in 1986, to join with the Direction de recherche agronomique of the Benin government and the Royal Tropical Institute (KIT) of the Netherlands in a project on "Recherche appliquée en milieu réel". The objective was to develop alternative methods to restore fertility by enlisting farmers' participation in a series of on-farm research trials.

Soil fertility had been declining in the Adja Plateau in Mono Province, southern Benin, under growing population pressure. Traditionally, to prevent loss of fertility, farmers in that area had planted 12-to-15-year fallows with oil palm, which is economically attractive because of the palm wine produced from the trees when the fallows were cleared. However, the increasing demand for food had lengthened the periods of cultivation and shortened the fallows, with the result that soils had become impoverished.

The initial round of experiments involved a set of maize trials planted in farmers' fields, and several researcher-controlled demonstrations of new soil-enriching technologies such as alley cropping, various cover crops, and live mulch. The experiments began in 1986, to be implemented over the 1986 and 1987 cropping seasons. As it turned out, these demonstration fields were to have the greatest impact on farmers' decision-making.

Farmers met periodically with project scientists and technicians, to discuss their experiences in the series of experiments and to participate in selecting new treatments for the coming season. Group discussions were very lively and farmers became well informed even about results from experiences with options which they had not selected.

Their curiosity to hear the impressions of others about the different options seemed to stimulate attendance at meetings. The group became so large that it had to be divided into two, each of which included the full range of options in its scope.

Impressed. In the demonstration plots, the way that mucuna had smothered the ubiquitous speargrass impressed many farmers. Hence, in 1988 and 1989, a number of farmers elected to grow mucuna as a planted fallow crop during the "short season" (so called because it is the shorter of two rainy seasons which are characteristic of the climate in this part of Africa). Some farmers elected to grow pigeon pea (*Cajanus cajan*) in their planted fallow. The pigeon pea barely grew where soils were very depleted, but mucuna seemed to perform better in similarly poor soils.

The trials confirmed mucuna's value as a weapon against speargrass. Even more important, the trials proved mucuna's capacity to restore fertility to the soil, resulting in greatly improved yields of maize during the following season. The accompanying chart of 1989 results shows that maize yields on plots earlier planted to mucuna were, on average, 80% greater than on continuously cropped land. Far smaller gains were recorded for maize on plots planted earlier to pigeon pea.

For 1990, the scientists and farmers next

Beninois researcher, farmer, and IITA researcher discuss mulching with mucuna.

planned optional treatments for two types of soil conditions which existed: (1) completely depleted fields, and (2) fields still reasonably fertile. The two options for the completely exhausted fields were mucuna and acacia trees, a fast-growing legume which would produce a snbstantial amount of slowly decomposing litter and high-quality fuelwood.

The mucuna was to be planted one month after sowing maize, during the first rainy season, and would grow to a dense cover during the second rainy season. Subsequently, during the dry season, the mucuna would die and form a dry mulch, which would fertilize the next year's first-season maize crop. Mucuna would once again be "relay planted" in this manner, one month after that crop.

The aim was to regenerate soil fertility to an adequate degree after several years of either mucuna cover crops or acacia fallow. Once the fertility of their fields had been restored, the farmers could decide whether to go on to one of the second set of options, in order to maintain soil fertility.

The results for farmers who had chosen mucuna were dramatic. They recorded, on average, a tenfold increase in maize yield (from 200 to 2,000 kilograms per hectare).

Even before those results had become evident, others had begun joining the ranks of the mucuna planters, attesting to its growing word-of-mouth popularity as a soil improver as well as a weapon against imperata. As a consequence of the demonstrated yield increase, 20 additional farmers with infertile fields chose the mucuna option in 1991, they obtained a threefold increase over the previous year's recruits.

National extension authorities were so impressed with the results that they decided to apply the technology from 1991 in all the agroecological zones of the country where soils are depleted and imperata is a problem.

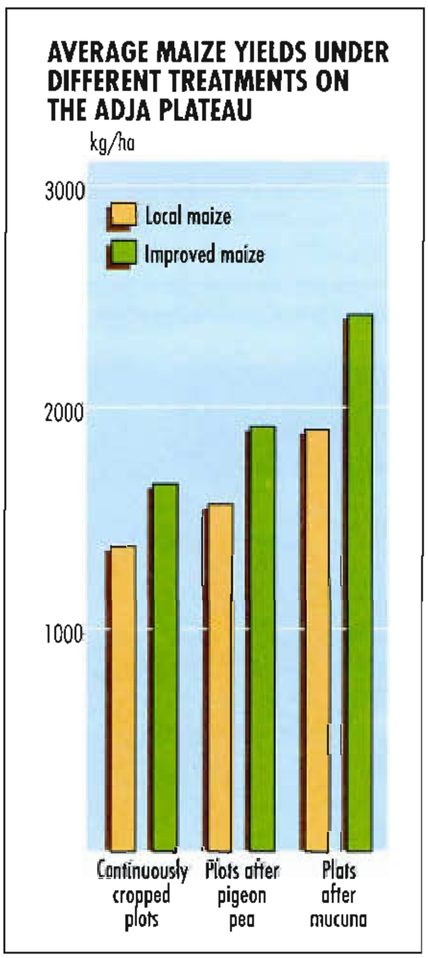
The results of adoption in the current nationwide phase will be studied from 1992, with documentation of the extent of adoption, characterization of areas where it has been successful, and a comparison between areas with characteristics favoring adoption and areas where the technology was actually successful.

Ingredients of success. Behind the snccess in promoting adoption of mucuna to date, a number of elements can be singled out as being major contributory factors.

Farmers were an integral part of the decision-making process, first of all, and they participated in groups which had been divided according to the types of problems under investigation. Those in the same groups shared similar problems—farmers in the 1990–1991 set of trials had joined discussion groups for either completely depleted fields or reasonably fertile fields. Consequently the groups enjoyed a unity of purpose.

Each group was offered a range of technologies to choose from. Every farmer could accommodate his particular problems among the options, or could discuss with his peers and the scientists how to tailor the technologies to them.

Moreover, farmers had had a chance to see demonstration plots showing the effects of mucuna and other technologies before they made a selection. They were not simply told about hypothetical benefits and asked to make a blind choice.



Finally, the dual impact of mucuna in restoring soil fertility and combating imperata appealed greatly to farmers, particularly those with few labor resources. Mucuna's bonus of imperata control had a decisive impact in the widespread adoption of this technology.

For the future, scientists with an interest in on-farm experimentation can draw on a fund of useful experience from the Benin mucuna trials. The farmers showed, in their contribution to refinements in the technologies, the fruitfulness of their participation in experiments which had been so designed as to bring out the benefits they had to offer.

INTERNATIONAL COOPERATION

The special role of international cooperation at IITA is to enhance the collaborative process with national agricultural research systems of adapting and applying improved technologies for farmers' needs.

COOPERATION STRATEGIES

The principal means by which IITA strengthens agricultural research are training, information dissemination, germplasm exchange, and other collaborative project activties which convey IITA technologies.

Four mechanisms have been designed to enhance usefulness of collaborative research and training actvities, and enable IITA to respond with greater sensitivity to perceived needs. They are:

- **Networking.** Collaborative networks link IITA with national and regional research institutions in Africa, to develop their research capabilities.
- **Research liaison scientists.** Three research liaison scientists, each with specific responsibilities for a group of countries, will be placed in Ghana, Côte d'Ivoire and Congo.
- **Resident scientist teams** in specific countries collaborate with national colleagues to meet research problems and needs, and to strengthen research capabilities.
- **Training.** IITA aims to encourage national programs and research networks eventually to do for themselves all the training that is needed to support their own research efforts. Training at IITA will focus on promoting effective research teams where both national programs and IITA are equal partners.

IITA scientist and counterpart Lesotho plant explorer appraise results of their cowpea collection efforts.

CREATING THE COWPEA THAT BUGS WON'T BITE

Intuitive pathways have begun to crisscross new areas where borders of traditional disciplines meet. A new network links scientific institutions on three continents in collaborative research which relates biotechnology applications in crop improvement, entomology, and food science.

Three years ago the group was formed from IITA's partnerships with several Italian institutes and with Purdue University, USA. Driving this collaboration is their common quest: to create a cowpea constituted with new genes that will enable it to resist insect pests and ensure better yields for millions of farmers in the developing world. The first signs that the goal was within reach came during 1991, with the momentous news that two of the partners had succeeded in transforming the cowpea in different ways.

A key crop. Cowpea (*Vigna unguiculata*) is a food legume, one of the few sources of dietary protein for many African peoples living in dry regions. Harvests are generally much lower than the productive potential of the plant, because no cultivated cowpea variety is resistant to the many pod-boring, pod-sucking, and storage insect pests which abound in tropical Africa. These pests have long eluded crop breeders, who have been able to incorporate genes for many other insect and disease resistance traits into cultivated cowpeas.

New biotechnological methods have, however, opened possibilities for improving a crop by adding new genes to the existing genotype—the genetic constitution of a plant that defines its specific characteristics. The candidate genes for this transformation would be those which could endow a plant with desirable characters that nature did not originally provide. IITA's partners, well equipped and already experienced in related applications of biotechnology, bring the necessary expertise to such a quest for a pest-resistant cowpea. They also share diverse research interests in the crop.

The search starts with the collected cowpea germplasm, the genotypes on which to base further development. Careful evaluation of the germplasm provides an inventory of traits, botanical and biochemical, some of which may be useful in creating the "ideal" cowpea. Of greatest value are traits which repel or discourage the pests from eating the various parts of the plant:

- pubescence or "hairiness" on the plant which inhibits insect feeding or egg laying;
- impenetrable or hard pods or seed coats;
- unpalatable chemical components of pods or seeds.

The targeted insects which cause the most damage and are difficult to control are, in order of research priority: *Maruca* pod-borers, various pod-sucking bugs, bruchid storage weevils, and thrips, which feed on the cowpea flower.

The collaborators are hunting the particular genes which express insect resistance traits in wild *Vigna*, or other species that may or may not be closely related to cowpea. The objective is to incorporate them into high-yielding cowpea genotypes. At the end of the quest, the group aims to have produced cowpeas with resistance to the target pests that they did not possess before, and that will enable African farmers to increase their cowpea harvests severalfold.

Two ways. The two ways to create the genetic improvement are by (1) "wide crosses", or crossbreeding of widely divergent genotypes of cultivated and wild *Vigna*; and (2) genetic engineering, by which foreign genes are incorporated into the cowpea and endow the progeny of that plant with new characteristics. The accompanying diagram shows how the work is divided among the collaborating institutions along these two paths to the genetically improved cowpea.

Wide crosses are hybrids between different species whose genotypes are normally incompatible with one another. The goal behind the attempt to forge such interspecific crosses is to introduce new genes which will act together with the existing genes to produce an advantageous feature—such as a durable form of resistance to insects or pathogens.

Genetic engineering techniques, on the other hand, entail use of a single gene to confer the desired trait on the selected species. The new gene, carrying the biochemical information responsible for the trait, is forcibly introduced into the target genotype, either by accelerated microparticle technology (a "gene gun") or a transfer process intermediated by, for example, the microorganism *Agrobacterium tumefaciens*.

Generally, resistance based on a single gene is less apt to be durable than a polygenic resistance—the pest or pathogen is more likely to survive and adapt if only a single resistance mechanism is present than if it has multiple mechanisms of resistance to overcome. To build a more broad-based set of resistance characters, several genes for resistance could be incorporated into the new cowpea. The selectivity which is possible in an engineered transformation would have the added advantage of excluding "weedy" or wild characters that tend to accompany wide crosses.

Both paths to genetic improvement are being explored. Scientists need to know the limits to possible exploitation in each case, and to compare the efficacy of the two approaches. The experience should yield valuable insights for work with other crops.

World collection. Since the 1970s IITA has had the mandate among international research centers to develop a world collection of cowpea germplasm. IITA scientists have worked with national research staff to collect specimens of cultivated and wild germplasm, describe their characters, evaluate their usefulness as potential sources of disease or pest resistance and other desired traits, and conserve them as genetic resources for crop improvement and for the benefit of posterity.

By the 1980s the collection of cultivated cowpea contained sources of resistance to many insect pests and diseases, but none to the major pests: the pod-borers and pod-sucking bugs. Wild species and close relatives of cultivated cowpea were the best sources to explore for the desired genetic material. It was clear that IITA's wild *Vigna* collection should be broadened, in order to represent a greater proportion of the extant biodiversity—until 1983 only 200 accessions of wild *Vigna* had been collected. Moreover, IITA's seed storage and laboratory facilities for genetic resources research needed to be enlarged and modernized.

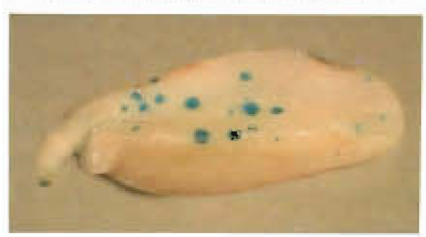
Once these prerequisites were satisfied, IITA could start to address basic breeding issues. They included the range of genetic possibilities within species, and genetic compatibility between cultivated cowpea and related wild species. With improved knowledge in those areas, scientists could begin to exploit the cultivated and wild cowpea potentials for resistance breeding, applying appropriate tools including biotechnology.

In 1984 the IITA Genetic Resources Unit began to tackle these needs in a project supported by the Italian government, working together with a consortium of four Italian institutes which shared complementary research interests in cowpea:

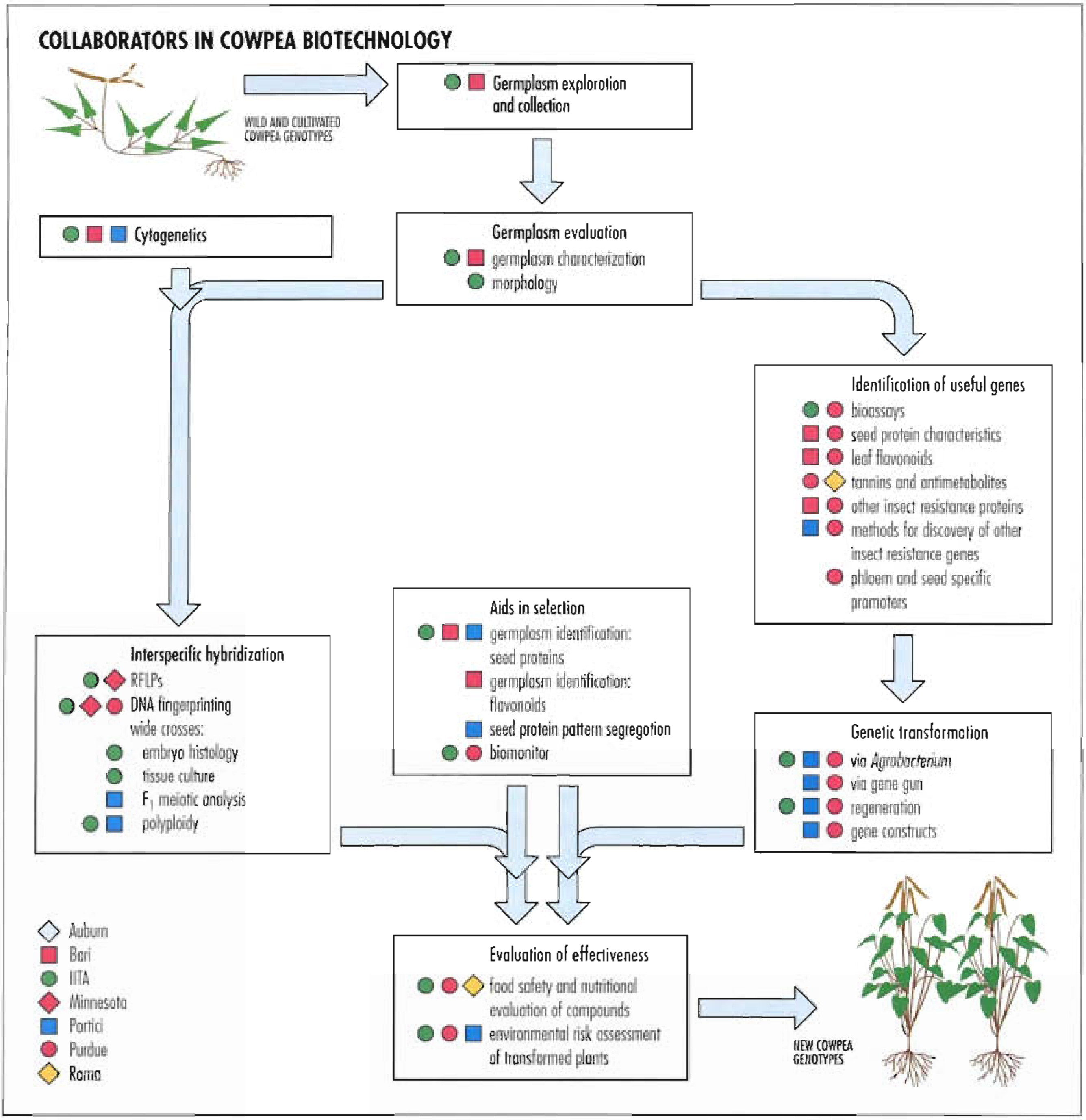
- Dipartimento di Scienze Agronomiche e Genetica Vegetale, Università degli Studi di Napoli, Portici (plant genetics)
- Istituto del Germoplasma, Centro Nazionale delle Ricerche, Bari (germplasm collection, characterization, and evaluation)
- Istituto Nazionale della Nutrizione, Rome (food safety, nutrition)
- Dipartimento di Agrobiologia e Agrochimica, Università degli Studi della Tuscia, Viterbo (plant cell regeneration)

Scientists in the Italian consortium were interested in working with IITA for the opportunity to contribute to African agricultural development, while expanding knowledge in their scientific fields.

The Italian and IITA researchers joined forces in order to strengthen their understanding of cowpea genetics and breeding. A biotechnology unit was established at IITA to make new knowledge and techniques avail-



Cowpea embryo genetically transformed by DNA particle gun – blue areas represent expression of introduced marker gene.



able to African colleagues. In 1989 new facilities were added to the unit with Italian support. They also began their collaboration in cowpea genetic improvement through wide crosses and transformation with a foreign gene. That year the two groups were joined by American researchers, mostly from Purdue University in Indiana, USA, to supplement the project with work on storage pest problems of cowpea.

At Purdue University, a group of scientists had come together from different disciplines during the 1980s to develop resistance characters for fighting insect pests of stored pulse crops in Africa and Latin America. Cowpea was a special focus of the group, which began by investigating the chemical and physical bases of resistance to storage weevils, among others. One of the group's long-term goals was to discover genes which could help engineer insect resistance into cowpea. Shared goals brought the Purdue team into a collaborative relationship with IITA scientists by 1989. Scientists from Auburn University and the University of Minnesota also contributed to the germplasm characterization and breeding efforts.

The Italian, American, and IITA groups merged into a group of collaborators in a joint program on cowpea biotechnology. They agreed to tackle different issues and problems according to their individual expertise, building on each other's advances and in turn contributing to the goals of the group.

Collecting germplasm. Plant explorers from IITA and the Bari Germplasm Institute have embarked on a series of collecting missions in central, eastern, and southern African countries and the Mediterranean region. They have made a special effort to explore southern Africa where the cowpea originated. As a result, by the end of 1991 the IITA world cowpea collection had added over 500 accessions of wild *Vigna* species. The total world collection now counts over 16,000 accessions from about 100 countries worldwide. That includes over 15,000 cultivated cowpea species and varieties, and some 1,500 accessions of wild *Vigna* of which about 500 belong to the primary genepool of wild cowpea. The entire collection is preserved in IITA's genebank, which was refurbished and expanded with Italian support in 1986.

Characterizing germplasm. IITA, the institutes at Bari and Portici, and Minnesota University are investigating the morpho/physiological characters of *Vigna* germplasm down to the level of chromosomes, for precise taxonomic classification. *Vigna* chromosomes have been poorly characterized in the past, partly because of their small size. Scientists are assessing insect resistance in order to identify possible sources of resistance genes. They are also studying the degree of relatedness between wild and cultivated species, which may be instrumental in estimating the feasibility of combining genes from wild species with cultivated cowpea.

Identifying resistance traits. Cowpea and other *Vigna* species are being grown in Nigeria and selected for the resistance they exhibit to the target pests. IITA entomologists have shown that several wild *Vigna* species have excellent resistance to pod-borers and pod-sucking bugs.

At Bari, biochemists are investigating the factors responsible for resistance to storage weevils. They are analyzing levels of certain compounds present in resistant and susceptible cowpea seeds. Purdue entomologists have demonstrated that wild cowpeas contain sources of resistance to weevils. They are studying biochemical factors which cause death or delay in maturity of weevil larvae.

Scientists at the University of Potenza, Italy, have contributed to the germplasm characterization work. They have studied the biochemical basis—flavor-producing compounds, for example—of resistance to aphids, which inflict damage on the plant and also carry cowpea viruses.

Interspecific hybridization. Early trials at hybridization among several species at IITA and Purdue either failed or produced infertile progeny, so Portici geneticists have conducted microscopic investigations of the physiological and physical barriers to crosses between cultivated and wild cowpea. Wide crosses are continuing at IITA and Purdue, with development of techniques for rescuing embryos that would otherwise abort and for identifying hybrids.

Portici scientists have joined IITA and Purdue colleagues in exploring the polyploidy phenomenon— plants with a multiple set of the normal chromosome number. Polyploidy, which can increase productivity in vegetatively propagated crops such as cassava, can also help to improve the success rate in interspecific hybridization, by overcoming the genetic barriers of incompatibility between cultivated and wild cowpea.

Geneticists at Minnesota are working with IITA colleagues to develop a cowpea DNA map utilizing RFLPS (restriction fragment length polymorphisms), preliminary to identifying and marking specific resistance genes for possible transfer.

Examining resistance genes. During the 1980s Purdue scientists began investigating genes responsible for enzymes which interfere with insect digestive processes. The idea was to induce malnutrition and eventually starvation by putting into the cowpea certain enzymes which would curtail the pests' ability to digest its food. Purdue is also experimenting with bioassay systems, to test the effects on pests of consuming those proteins.

Meanwhile, the Italian groups have already become involved in the biochemical characterization of seed proteins and studies of mechanisms of insect pest resistance. Together with scientists from Auburn University (USA) and IITA, they have joined the search for new genes for pest resistance and new methodologies for making those discoveries.

Transforming the cowpea. In 1991 the Portici researchers, following the wide crosses approach, confirmed that their techniques of using *Agrobacterium* as a vector have yielded cowpea embryos which show signs of transformation. And the group at Purdue verified that microparticle bombardment techniques with a "gene gun" had produced transformed embryos. Scientists from both institutions are working closely together to ensure successful outcomes in these key developments.

Preliminary work in regenerating a cowpea plant from a single cell was conducted in 1987 by Italian scientists at the institute in Viterbo. That approach will be pursued again in future.

Aiding the efforts. IITA scientists have been working with Purdue and Minnesota colleagues to develop methods for identifying hybrids by "fingerprinting" DNA (deoxyribonucleic acid), the chain-like molecule carrying the code of genetic information that is unique to each genotype. They have also collaborated in developing a genetic map using RFLPS, which can help in specifying the location of desirable genes on chromosomes. The RFLP work will be useful as well in breeding, verification of hybrids, and the identification and characterization of germplasm.

A Purdue team of entomologists and an electrical engineer have invented a biomonitor, which makes use of ultrasonic signals in detecting hidden insects as they feed within dry materials such as seed grains. The biomonitor measures feeding behavior of pests as they consume cowpeas or artificially formulated grains. The goal is to screen different seed proteins for insect resistance, which can be observed in the feeding response of the insects with different formulations. The more resistant proteins may become candidates for new breeding efforts.

Assessing food safety. Transformed cowpeas will contain new protein substances not present in traditionally consumed varieties. These new proteins must first be tested for health hazards to consumers. Taste, texture, and cooking factors are being tested as well, to ensure that consumers will not object to perceived changes in their customary cuisine.

Food scientists at IITA, the National Institute of Nutrition in Rome, and Purdue are studying the safety, nutritional value, palatability, and "cookability" of proteins associated with insect resistance in wild and cultivated cowpeas.

Networking with users. As the activities and first achievements of the cowpea collaborators show, biotechnology applications afford a high degree of precision in the design of a product. That capacity calls for

Pod borer larva on cowpea callus in a bioassay test of the efficacy of cowpea pest resistance characters.

the producers of the new technology to work more closely than ever with national agricultural scientists, who are in the best position to know the needs of the ultimate users: the cowpea farmers.

As biotechnology telescopes the distance between basic research and farmer use, the character of the research process shifts dramatically. Before biotechnology made shortcuts available, crop improvements had to evolve step by step, involving adaptation and finetuning at several levels—from advanced laboratories to international centers, and thence to national programs for adaptation to local requirements. But the biotechnology research effort, from the beginning, is driven by the farmers' specific needs, not by the dictates of the research process.

In the cowpea biotechnology collaboration, IITA will be able to use its special relationships with national programs to advantage, in the design of the biotechnological product. IITA will also be able to bring national scientists within the operational scope of this advanced research, through training at its own biotechnology facilities where the work is being done. While the research and its benefits appear awesome, they can come within the reach of national programs in Africa through the continued bridging role of their international center, IITA.

NEW SUPPORT TO SUSTAIN THE SUCCESS

STRENGTHENING NATIONAL PROGRAMS IN BIOLOGICAL CONTROL

African cassava crops are flourishing again after a wave of devastation by the cassava mealybug during the 1980s—a wave that was broken by IITA's continent-wide biological control campaign. In the wake of this success, which national programs helped to achieve, IITA is in turn helping countries to build up their capacity to manage their own biological control programs against pests of cassava and other crops. Boosting national capability is the best way to develop crop protection systems, especially sustainable systems which call for ecological awareness and a well-coordinated balance of activities.

Biological control is a mainstay—together with host plant resistance and habitat management—in the IITA scheme of good plant health management. One of its main attractions is its ecological soundness, in controlling a pest which has gotten out of hand by mobilizing its natural enemies which will reduce the threat to a tolerable level. Its environmental advantages, not to say economic ones, over the use of pesticides are obvious. Moreover, awareness of the adverse environmental effects of pesticides has made donor agencies reluctant to finance their usage and compelled governments to seek non-chemical options to reduce crop losses.

The Africa-wide biological control campaign reduced damage by the cassava mealybug in 95% of all fields to a level below economic impact, the status of that exotic pest's impact in its home environment in

South America. The success of the mealybug campaign has opened the way for African policymakers and researchers to develop biological control and other environmentally friendly alternatives to pesticides.

A high degree of capability and coordination is needed in-country to research and implement sustainable crop protection systems. During 1991 IITA began collaborating with the German donor agency Gesellschaft für Technische Zusammenarbeit (GTZ) on a special project for technology transfer and training, whose goal is to establish sustainable crop protection programs in Africa with a strong basis in biological control. The special project is reinforcing IITA efforts which are supported by other donors to strengthen national biological control activities. Activities concerning the targeted pest(s) in each country covered by the project are noted in the accompanying table.

The special project first seeks to ascertain governmental commitment to the goals of sustainable crop protection. The success story of cassava mealybug control stimulates enthusiasm, while participation in biological control conferences and training courses usually convinces decision-makers and technical officers alike of the efficacy of the approach.

Project activities follow four main channels: research, implementation, training, and program strengthening. The guiding belief is that such assistance should buttress resolve within the national progam to conduct its own activities and to make available local resources to the fullest possible extent. Creation of new institutions is not part of the plan—existing infrastructure remains the basis for development. The project provides a resource package or "biokit" to each participating country, comprising:

- an insectary
- a vehicle
- equipment for laboratory and office
- an in-country training course
- operating funds of a negotiated amount.

During the first project year, the cassava mealybug, cassava green mite, mango mealybug, banana weevil, and two pests of maize, the stem borer and larger grain borer, were targeted in control activities among the participating countries. The accompanying chart summarizes project activities by country and by targeted pest.

Research. In general, assistance in applied research began during 1991 with training and helping local staff in identifying the status of the specific pest in each country listed in the table. Next, the role of "beneficial bioagents", or natural enemies, and possibilities for establishing them had to be assessed. An appropriate strategy for pest management was devised in each case, which might also include host plant resistance, various cultural practices and rational utilization of pesticides. If natural enemies of a specific pest were already available, the beneficials were first reared in adequate numbers for release. Suitable release sites had to be found, import permits secured, the shortest transport itineraries determined, and the release itself organized and completed. Subsequently, in evaluating results of the control effort, three developments had to be assessed: the establishment of beneficials, their spread, and their impact on the pest and the crop. In the case of cassava mealybug and cassava green mite, evaluation surveys must extend over at least three years to be conclusive. Scientists in the national programs were equipped to conduct their own testing and monitoring of beneficials under the guidance of IITA scientists working on control of the particular pest.

Implementation: technology transfer. The project assessed the material and equipment needs of nine countries, and procured "biokits" for all but one (because of political unrest). Nine countries received operating funds for field work and in-country training seminars. IITA scientists advised six national programs on how to organize mass-rearing of natural enemies locally. During 1991 the programs in Burundi, Rwanda, and Tanzania asked to have insectaries installed for *Epidinocarsis lopezi*, a

Insectary in Rwanda containing "cassava trees", part of the biokit for developing the national program.

parasitoid of the cassava mealybug. Besides erecting a screenhouse in these countries, IITA trained local staff in equipment use and all facets of insect production.

Training. During 1991, three countries held their own seminars for altogether 70 participants drawn from their respective staffs. University students, government officials, and other guests were invited to the program stations to familiarize themselves with the work and promote interest in the project. In addition, two group training courses were organized at the IITA Benin Station, Cotonou, where biological control scientists attended from 26 national programs. In the first year of project support, four PhD students and two MSc students from different countries began their studies. They eventually will join the corps of trained scientists in their respective national programs.

Strengthening: program development. IITA signed agreements during the year with the nine countries listed in the table, for strengthening of their programs. A project for support of five more countries was approved by the Austrian government. An IITA/CIAT project for additional assistance to four national programs (Benin, Cameroon, Ghana, and Nigeria) was submitted to UNDP for funding approval [which was granted in May 1992—*Ed.*]. The joint project concerns environmentally sound, ecologically sustainable plant protection for cassava.

SPECIAL PROJECT ACTIVITIES BY COUNTRY AND TARGETED PEST

Country	Pest type: cassava mealybug	cassava green mite	mango mealybug	maize stem borer	larger grain borer	banana weevil	IITA–Government agreement [A]: GTZ	Austria	UNDP
Angola								yes	
Benin									yes
Burundi	■ ◇	■					yes	yes	
Cameroon	■	■							yes
Central African Republic	■								
Côte d'Ivoire			■◇	■					
Gabon	■		■◇				yes		
Ghana		■	■◇	■				yes	yes
Guinea	■ ●		■ ●		■ ●	■ ●	yes		
Kenya	■ ◇						yes		
Malawi	■								
Namibia								yes	
Nigeria	■◇	■◇	◇						yes
Rwanda	■◇						yes		
Senegal	■◇						yes		
Sierra Leone	■ ●	■	■◇●				yes		
Tanzania	■◇●							yes	
Togo	◇●		■◇						
Uganda	◇	◇				■	yes		
Zaire	■◇●	■●◇	■◇●				yes		
Zambia	■◇								

■ research
◇ implementation
● training (in-country)

[A] Agreements between IITA and national programs for strengthening programs

All the national programs reported to have special project activities also received "strengthening" assistance from the project

RESEARCH COLLABORATORS

AT THE CRITICAL STAGE BETWEEN LAB AND FARM

On-farm experimentation is a key stage in developing any agricultural technology—that is where newly designed technologies first meet the test of real farming conditions, before they are released for widespread demonstration and extension to farmers.

On-farm experiments provide researchers and farmers with an opportunity to interact, in adjusting technology designs so that they best suit local conditions in the farming system and environment. It is a crucial stage for national research programs to manage, because it involves adapting technologies from various sources for indigenous use.

Scientists in different African countries have evolved methods and procedures for on-farm research, utilizing different models according to their training and institutional environment. As a result, on-farm research approaches may vary considerably from country to country. Some might be more effective than others in meeting certain kinds of problems.

As a means to enable those in different countries to learn from the experience of their peers in other programs, and to develop a comprehensive body of knowledge about on-farm research relevant to Africa, IITA has helped to set up two groups of scientists for collaboration in crop improvement and cropping systems research, for maize and root crops:

- Collaborative Group on Maize-Based Systems Research (COMBS), established in 1989.
- Collaborative Group for Root and Tuber Improvement and Systems (CORTIS), established in 1991.

The two groups of collaborators are composed of member institutes involved in crop improvement and/or cropping systems

IITA and national program researchers evaluating AFNETA on-farm research in Benin Republic

research, in both francophone and anglophone African countries. Apart from IITA, 10 institutes in 6 countries form the COMBS membership, while 15 institutes in 13 countries compose CORTIS. Four of those institutes are members of both.

The two groups have a common set of goals in their respective fields, and are breaking new ground in the region in the development of research capability. Their primary concern is to strengthen technical proficiency in specific areas of crop research, through development of on-farm research concepts, methodologies, and practices.

Both groups have agreed to collaborate in tackling issues of common concern among their members. At the same time they recognize the heterogeneity as well as location-specific nature of farming systems. Hence, their collaboration will focus on developing new approaches and methodologies, rather than testing the performance of individual technologies.

Some of the research issues on their respective agendas to investigate concern various approaches to:

- maintenance of soil fertility through various means, including intercropping with legumes, alley cropping, planted fallows.
- weed control.
- on-farm evaluation of new crop varieties.
- postharvest processing and storage.
- improvement in analytical techniques, such as multivariate analyses.

Each group started with a plan to collaborate on a research project. COMBS concentrates on soil fertility improvement and weed control through testing of technologies involving leguminous species. CORTIS is also interested in the use of leguminous species to reverse decline in soil fertility levels, but focuses on the selection and testing of appropriate crop varieties for different farming systems.

Itinerant seminars. The two groups hold annual workshops on a rotational basis at member institutes. Participating scientists critically review current work and approaches to farming systems research, and develop new thinking on methodologies and technologies. The workshops constitute an itinerant seminar, with a presentation of ongoing work by the host institute for that year and progress reports from the other members.

From the beginning, both groups aimed at providing technical support among their member institutes through exchange of visits or longer-term attachments. One instance of a need for technical support is backstopping for on-farm adaptive research in maize and cassava being sponsored by the European Economic Community in most of the COMBS and CORTIS member countries.

Both COMBS and CORTIS have decided that the West Africa Farming Systems Research Network (WAFSRN), with its documentation center and established contacts, should continue to help coordinate their respective activities. WAFSRN has the resources to provide them with an umbrella coverage in disseminating and receiving scientific information, channelling funding and administrative support for project activities and training courses, and generally liaising with kindred scientific bodies.

The formation of COMBS and CORTIS, and their accomplishments to date (see reports in the following paragraphs), show that the significance of on-farm research has been recognized by the agricultural research community. To IITA the link with national programs in this area of research activity is vital, in two ways: in extending the benefits of its own knowhow in working with farmers, and in expanding the pool of experience with new technologies.

The discipline of on-farm research lies at the heart of the adoptive research process. On-farm research is central to the role of national agricultural research systems, in developing technologies for extension workers to deliver to farmers. COMBS and CORTIS are providing essential support to strengthen this aspect of the national programs' operations.

COMBS

The Collaborative Group on Maize-Based Systems Research (COMBS) was formed in 1989 to bring together West and Central African maize researchers in a working relationship. Its main goal is to develop and test improved production technologies for maize-based cropping systems, guided by an understanding of farmers' constraints and opportunities. The group also aims to take advantage of opportunities to transfer successful technologies through the association of most national programs with development and extension organizations.

COMBS is concentrating on ways to integrate leguminous species into farming systems, in order to improve soil fertility and help control weeds. The main challenges are to select the right species to function in specific ways in the farming system, and to involve farmers in the design and experimentation stages.

The 1990 annual workshop in Ghana examined technological problems related to this central topic. A paper which incorporates the results of the discussions has since been produced under the title "Legume-based technologies for soil fertility improvement and weed control—an approach to technology targeting". The group has begun to assemble a database of detailed information on more than 200 legume species.

The 1991 workshop in Benin reviewed methodologies for expanding farmer participation in on-farm experimentation. The discussions were guided by recent experiences of the Benin members in working with farmers on legume-based technologies. (See article on farmer participation in the Resource and Crop Management section of this report.)

The national member institutions of COMBS are:

Benin:
Projet de recherche appliquée en milieu réel (RAMR) de la Province de Mono, Direction de recherche agronomique (DRA), Niaouli

Cameroon:
Institut de recherche agronomique (IRA), Bamenda and IRA, Garoua

Côte d'Ivoire:
Institut des savanes (IDESSA), Bouaké

Ghana:
Crops Research Institute (CRI)/Ghana Grains Development Project (GGDP), Kumasi
Crops Research Institute (CRI)/Nyankpala Agricultural Experiment Station (NAES), Tamale

Nigeria:
Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Ibadan
Institute for Agricultural Research (IAR), Samaru

Zaire:
Service national de recherche appliquée et vulgarisation (SENARAV), Kinshasa

IITA is represented in COMBS by scientists in the Savanna Systems Research Group.

CORTIS

CORTIS was formed in 1991 as a means of integrating two streams of root and tuber crop research: breeding/improvement and crop management.

The CORTIS goal is to encourage interaction between scientists in both streams for additional impact, and to avoid duplication of effort. The ultimate aim is to produce improved technologies for root-and-tuber-based cropping systems, to help increase farmers' productivity and help them meet the food needs of rapidly growing populations.

The founding meeting was held in June 1991 at IITA, when two committees for breeding and cropping systems were elected. The member institutes selected "Weed control and soil fertility maintenance through the use of leguminous species" as a topic for joint research. The new committees met to develop an action plan in September, at the Ekona station of Cameroon's Institut de recherche agronomique (IRA).

To begin research on the introduction of legumes into root-and-tuber cropping systems, the members decided to characterize their target zones and cropping systems using procedures similar to those developed by COMBS. Criteria for selection of appropriate leguminous species will be based on the characterization of the biophysical and socioeconomic environment and cropping patterns.

The members agreed to collaborate in varietal testing on farm, with the involvement of breeders as well as agronomists and farmers. The varieties to be tested will be selected in conformity with farmers' needs, with the aim that experimental results reflect a positive response to the selection from farmers. A framework for varietal targeting and on-farm testing is being developed. A training workshop on the topic is being organized.

The national member institutions of CORTIS are:

Benin:
Direction de recherche agronomique (DRA), Niaouli

Cameroon:
Institut de recherche agronomique (IRA), Nkolbisson and IRA, Ekona

Côte d'Ivoire:
Institut des savanes (IDESSA)

Ghana:
Crops Research Institute (CRI), Kumasi

Guinea:
Centre de recherche agronomique, Foulaya-Kindia

Nigeria:
Institute for Agricultural Research and Training (IAR&T), Obafemi Awolowo University, Ibadan
National Root Crops Research Institute (NRCRI), Badeggi
University of Ibadan

Kenya:
Coastal Agricultural Research Station, Kikambala

Malawi:
Ministry of Agriculture, Bvumbwe Research Station, Limbe

Mozambique:
National Agricultural Research Institute (INIA-DASP), Maputo

Rwanda:
Institut des sciences agronomiques du Rwanda (ISAR), Butare

Sierra Leone:
Institute of Agricultural Research (IAR), Freetown

Tanzania:
Ministry of Agriculture, Mwanza

Zaire:
Service national de recherche appliquée et vulgarisation (SENARAV), Kinshasa

IITA is represented in CORTIS by scientists in the Humid Forest Systems Research Group.

The French name for CORTIS is Collaboration pour les systèmes et l'amelioration des plantes à racines et tubercules (COSART).

NETWORKS

Networks are associations of scientists or multidisciplinary groups that have a common goal. The aim is to complement research programs within and across national boundaries. Network activities can be limited to information exchange, or encompass collaborative planning, implementing, and monitoring of research activities. Each participant in a network usually assumes a specific responsibility for the benefit of the network. International agricultural research centers such as IITA, and other institutions in developed countries, support and complement research in the network member countries.

In the following pages are reports on current activities of the three networks which IITA helps to coordinate:

- Alley Farming Network for Tropial Africa (AFNETA)
- East and Southern Africa Root Crops Research Network (ESARRN)
- The Soil and Plant Analytical Laboratories Network of Africa (SPALNA)

AFNETA: a village-level approach

The year 1991 represented the third year of the first phase of the AFNETA research program (1989-1994). The major objective of the phase is to establish the basic trials required to assess or demonstrate the biological feasibility of the alley farming system. The phase is also seen as the "experience-building" phase for most of the national program scientists who have had little experience of alley farming, and therefore require a period of orientation and familiarization with its principles, methods, and practices. Now that this phase is coming to an end, the focus of the network is on how adoptable alley farming is. Emphasis has thus shifted from on-station trials to on-farm trials.

Two types of on-farm trials are being conducted: (a) experimental on-farm research which aims to validate the different components of on-farm research such as alley farming/planted fallow/traditional farming, etc., and (b) developmental on-farm research which assesses the adoptability of a particular system such as alley farming.

The experimental type of activity has received much more attention and has constituted the bulk of on-farm research to date. Trials on components of alley farming are conducted at different sites with different levels of farmer participation. It produces results which can be analyzed statistically.

Developmental on-farm research represents the new focus in on-farm research. It involves three main steps.

The first step (exploratory) has a demonstration objective. The goal is to get alley farms established on few farmers' plots (maximum of five farmers) within a particular target area, for demonstration and practical purposes. Farmers may be approached on individual basis for this phase of activity. Researcher input and involvement in actual field work is high at this early stage, since farmers' understanding, perception, and commitment will as yet be low. The farmer, however, clears and prepares the land, and plants his food crop, before the researchers come in to organize the establishment of the tree hedgerows. Throughout the establishment period, the researchers need to visit the farmers regularly to discuss management and operational issues and observe progress of the trees.

The second step (intermediate), aims to increase farmers' understanding and involvement in field activities, and allows the initial assessment of farmers' interest and capability in the establishment and management of alley farms. It involves participation of farmers in groups of between 10 and 15. Farms established during the exploratory phase are used as demonstration farms to explain the concept, structure, and management of the system to these new farmers. They are able to see and understand the experimental results and are able to play a more direct and increased role in the establishment of the hedgerows. Both researchers and farmers are responsible for all field activities during this phase and a lot of effort goes into identifying farmers' concerns and impressions.

The third and final step in the developmental on-farm research process is the pilot project, which involves the introduction and assessment of the system at the community level. This is the point at which extension involvement is at peak and extension

Discussing results of alley farm research with cooking bananas and leucaena hedgerows near Mityana, in Uganda.

methodologies are used to introduce the concept to the farmers' community for assessment of its adoptability. Researcher involvement in actual field operations is completely withdrawn, and farmers take on full responsibility for establishment and management of their alley farms. The farmers are made to see the alley farms as their own plots rather than as research plots. They are free to make modifications that they consider necessary, and adjustments in the operation schedule, to fit their own circumstances. Issues, both socioeconomic and biological, that might arise as a result of introduction of the technology are identified and discussed.

Collaboration of an agricultural extension or development agency is necessary for the proper implementation of this phase, which is considered as the nucleus of the research/extension overlap in technology transfer.

At the end of this instructional and relationship-building process, farmers who indicate their willingness and eagerness to be involved in trials are enlisted and provided with seedlings to establish their own alley farms.

On-farm activities are being conducted by 11 national programs in the humid and subhumid zones where there is relatively more experience and information on the system. Most of the other sites are just getting started. However, there is no doubt that on-farm research is essential to assess the adoptability of alley farming. During the second phase of the program, the network plans to concentrate wholly on this on-farm approach.

ESARRN: solid grounds for root crops

Established in 1987 with 11 countries as members, the East and Southern Africa Root Crops Research Network (ESARRN) aims to increase cassava and sweet potato productivity among resource-poor farmers in East and Southern Africa, through adoption of technologies which stabilize production and optimize productivity while sustaining the resource base. The first phase, which ends in September 1992, aims to develop research collaboration among national programs and support the transfer, exchange, and adoption of improved varieties, agronomic practices, postharvest, and other improved technologies for cassava and sweet potato production and utilization. Collaborative research and training are the chief mechanisms for strengthening national programs. Expected project outputs of the first phase are:

- An effective collaborative regional research system supported by national programs;
- Generation of useful germplasm and improved varieties adapted and acceptable to farmers and consumers;
- Benchmark database for cassava and sweet potato production, cropping systems, and production technologies;
- Characterization of postharvest handling, rural processing, and utilization of cassava;
- Effective transfer of germplasm and multiplication of varieties in the region and promotion of farmer adoption; and
- Production technologies that are economically viable and sustainable.

Funding of the network is provided by the United States Agency for International Development (USAID) and International Development Research Centre (IDRC). IITA provides technical backstopping on cassava, while Centro Internacional de la Papa (CIP) supports sweet potato research.

Exchange of superior germplasm by the national programs has gradually increased since 1988 when Rwanda was the only country generating and distributing germplasm. Multiplication and distribution of selected high yielding varieties have also gained momentum. In Rwanda, for example, 80,000 slips of sweet potato and 180,000 cuttings of cassava were distributed in 1984. This increased to 9.3 million slips of sweet potato and 800,000 cuttings of cassava by 1991. Farmer adoption has been promoted by numerous field days on farmers' fields as well as on-station. On-farm trials and demonstrations promoted by the programs in Uganda, Malawi, Zambia, Rwanda, Mozambique, and Tanzania also offer opportunities for rapid farmer adoption. In Rwanda, for example, an average yield of 25 tons/ha of fresh cassava roots is obtained under improved management with improved varieties compared with 10 tons/ha under traditional management with local varieties.

IITA jointly sponsors the collaborative study of cassava in Africa (COSCA) which is designed to address the socioeconomic aspects of cassava production in major cassava growing countries of Africa. Initially, COSCA surveys were conducted only in Uganda and Tanzania. However, through ESARRN, they have been expanded to include Zambia, Kenya, Rwanda, Burundi, and Malawi.

Through COSCA useful information is being obtained on the social aspects of cassava and sweet potato production. Preliminary results of COSCA studies indicate that five basic food products can be obtained from cassava: flours, granules, fermented paste, sediment starches, and boiled fresh roots. In addition, cassava leaves are eaten as vegetable and fermented drinks are made from the roots.

ESARRN also plays an important role in the characterization of postharvest handling, rural processing, and utilization of cassava and sweet potato in the region. Rapid sun-drying and storage technologies which will reduce postharvest losses of cassava are also being developed in Uganda, and new foods from fresh cassava roots are being tested in Zambia and Malawi.

Although all network objectives have not been fully realized, root crops now occupy an important place in the national research priorities of the region. This is reflected in both government planning documents and budget allocations. In Malawi, root crops have been designated the second most important crop. Root crops have also assumed greater importance in Rwanda, Zambia, Uganda, and other participating countries. Government has also paid more attention to training. Since 1987, 14 national program staff have been trained at PhD level and 16 at MSc level. In addition, 907 national programs staff attended in-country training courses while 17 attended regional courses.

SPALNA: towards better analytical services

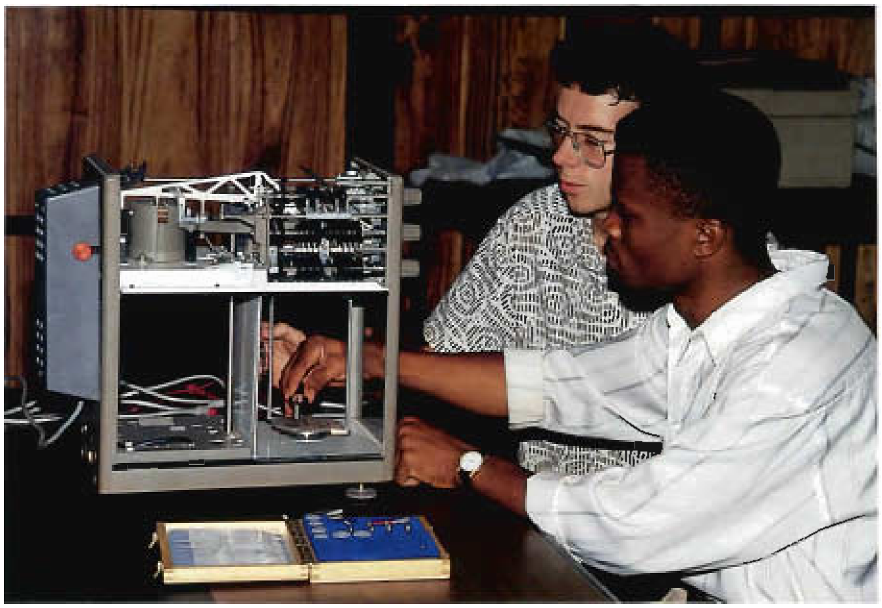
Established in February 1991, the Soil and Plant Analytical Laboratories Network of Africa (SPALNA) is one of the first attempts at collaboration among laboratories. It aims to improve soil and plant analytical services to support research in national agricultural institutions in Africa. At present it has more than 100 laboratories in 30 African countries as members.

The network emerged from the training courses on soil and plant analysis organized by IITA since 1980. In discussions among participants, it became evident that soil and plant analysis laboratories in Africa face similar problems which are difficult to solve individually. The most important issues are:

- Equipment maintenance: Most of the laboratories depend on imported equipment which is very expensive and difficult to maintain, due to nonavailability of spare parts and lack of trained maintenance personnel.
- Training: No African university/polytechnic offers courses in soil and plant analysis, and use of laboratory equipment. Hence training is often on an ad hoc basis.
- Supply of equipment, chemicals, and consumables: Most of the equipment and supplies needed are imported. Hence, there is usually a delay in purchasing them, added to the fact that supplies get mixed-up, lost, expired before they arrive, etc.
- Quality control of data: Data from laboratories in Africa are of low quality due to equipment problems, low purity of chemicals, unskilled staff, lack of reference samples, etc.
- Collaboration: Laboratories in Africa are deficient in so many areas. Hence it is difficult for them to function efficiently. The similar nature of the problems and the inability to solve them individually necessitates a collaborative effort.
- Infrastructure: Water and electricity supply to African laboratories is very erratic and present a major constraint to the efficiency of operations.
- Laboratory management: Laboratory managers need to be exposed to new management techniques and tools, particularly in laboratory information management.

SPALNA has selected an international coordinator and a general secretary, and will begin to publish a biannual newsletter early in 1992.

With its varied experience in networking, IITA is providing support to the establishment of the network in various areas. IITA helps



Helping to improve equipment and techniques in member laboratories.

design training courses and training materials relevant to the needs of network members. Courses will be designed to improve the skills of the technicians and train new technicians. Such courses will cover laboratory management, quality control, equipment maintenance, etc. The first course on equipment maintenance will take place at the University of Nigeria, Nsukka, in October 1992.

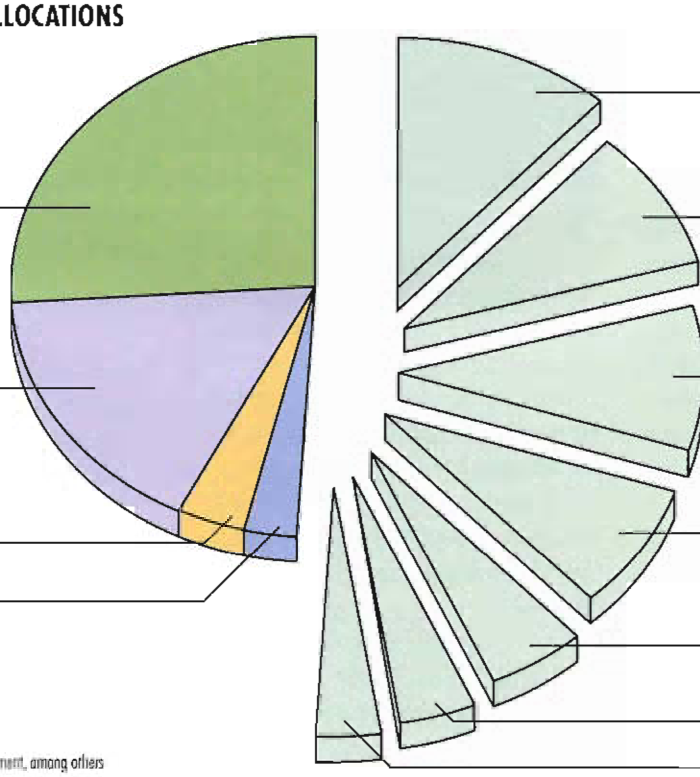
The network also hopes to centralize the purchase of supplies in order to ensure that high quality materials are available to its members.

To encourage collaboration, check samples will be distributed among laboratories and a database of existing equipment and expertise in equipment maintenance will be established for member laboratories to consult. To address the infrastructure problem, it is hoped that eventually all collaborators will be self-sustaining—have their own power generators or boreholes, for example.

FOR THE RECORD

MAJOR RESOURCE ALLOCATIONS

Values in US $ thousands



[A] Net of overhead recoveries

[B] Includes Biometrics, Analytical Services, Genetic Resources, Virology, Farm Management, among others

INVENTORY OF RESEARCH PROJECTS

Project title	Funding sources	Cooperating institutions	Location	Duration
COMMODITY IMPROVEMENT DIVISION				
Root and Tuber Crops				
Cassava germplasm introduction, evaluation, and distribution	core	CIAT, EMBRAPA, NARS	Colombia, Nigeria	continuous
Cassava germplasm enhancement	core	NARS, ANU, RVAU	Australia, Denmark, Nigeria	continuous
Yam germplasm evaluation and distribution	core	NARS	var. sites, W & C Africa	continuous
Yam germplasm enhancement	core	NRCRI	var. sites, W & C Africa	continuous
Postharvest technology	core	KU Leuven	Belgium, Nigeria	continuous
Maize				
Maize breeding for the savanna				
Yield potential	core	IAR	Nigeria	continuous
Striga resistance	core	NCRE/IRA, UI	Nigeria	continuous
Nitrogen use efficiency	core	UI	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
Drought resistance	core	SAFGRAD	Nigeria	continuous
Grain quality and utilization	Guinness Nigeria Plc	IAR&T/IER	Mali, Nigeria	continuous
Maize breeding for the forest				
Downy mildew resistance	core	IAR&T	Nigeria	continuous
Stem borer resistance	core	—	Nigeria	continuous
Husk cover and weevil resistance	core	Univ. of Benin	Benin	continuous
Grain quality and utilization	Guinness Nigeria Plc	IAR&T	Nigeria	continuous
Maize breeding for the midaltitudes				
Yield potential	core	UTC, NCRE/IRA	Nigeria	continuous
Disease resistance	core	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, Côte d'Ivoire, Burkina Faso	continuous
Outreach				
SAFGRAD	USAID	SAFGRAD/OAU/USAID	Niger	continuous
International trials	core	NARS	Nigeria	continuous
Collaborative research with NARS	—	NARS	Nigeria	continuous
Plantain/Banana				
Plantain/banana breeding for durable host plant resistance to sigatoka disease	USDA/ARS, NIHORT, CRBP, AGCD	INIBAP, KU Leuven	Nigeria	1987–
Musa germplasm enhancement using in-vitro culture techniques and biotechnology	USDA/ARS	INIBAP, KU Leuven	Nigeria	1983–
Development of improved systems for sustainable and perennial plantain production		KU Leuven	Nigeria	1980–
Genetic Resources				
Interspecific hybridization of *Vigna* spp.	Italian universities, Italy	Purdue Univ.	Nigeria, USA	1989–
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	1989–
Virus characterization and diagnostics	VRS, Univ. of Missouri	VRS, Univ. of Missouri	Canada, Nigeria, USA	1990–
Grain Legumes				
Breeding for resistance to *Maruca* pod borer and pod sucking bugs in cowpea	core	LI	Nigeria	1989–
Cowpea varietal development for humid forest and Guinea savanna zones	core	—	var. sites, W & C Africa	1971–
Cowpea international trials	core	—	var. sites, W & C Africa	continuous
Nationally coordinated research on cowpeas	NSS	IAR	var. sites, W & C Africa	1975–
Cowpea improvement for cereal-based systems— improvement of local varieties; genotype x environment analysis; resistance to *Striga*, *Alectra*, and *Maruca*	core	IAR, ICRISAT, ABU, Univ. of Reading	Nigeria	1990–
Soybean breeding for the savanna	core	—	var. sites, W & C Africa	1978–
Soybean international trials	core	—	var. sites, W & C Africa	1982–
Studies on promiscuous nodulation	NIFTAL	NIFTAL	var. sites, W & C Africa	1982–
Yield physiology of cowpea including studies on photoperiodicity, temperature response, water, radiation use	core	Hawaii, Univ. of Reading	Nigeria	1989–92
Intercrop physiology of cowpea	core	—	Nigeria	1989–92
Development of cowpea and soybean for Ghana	CIDA	CRI, GGDP	Ghana	1985–

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	1982–93
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–
Impact of African cassava mosaic virus on yield and development of a new disease resistance rating system	—	—	Nigeria	1991–92
Yam, Sweet Potato				
Biology and control of yam anthracnose	—	—	Nigeria	1992–93
Development and testing of sweet potato virus cDNA probes	—	Agriculture Canada	Canada, Nigeria	1990–93
Maize				
Analysis of the maize ecosystem with focus on the most important lepidopterous pests of West Africa	core, UNB	CABHE, 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	Old Dominion Univ., Univ. of Hohenheim, IAS, Univ. of Nsukka	Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Nigeria, Togo	1989–95
Characterization of maize pathogens	core	NRI, Texas A&M Univ.	Nigeria	1991–95
Epidemiology, vector biology, and resistance breeding of maize streak virus	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, Rockefeller	ETH, Univ. of Laval, AUW, UC, ABU, IRRI, ILCA	Benin, Netherlands, Nigeria, Philippines	1987–95
Studies on virus diseases of cowpea	—	AUW	Mozambique, Nigeria	1990–93
Soybean				
Studies on frogeye leaf spot disease	—	NCRI, EMBRAPA	Nigeria	1991–94
Biology of red leaf blotch	—	Univ. of Jos	Nigeria, Zambia	1991–93
Plantain/Banana				
Biology of *Mycosphaerella fijiensis*, causal agent of black sigatoka disease	—	—	Nigeria	1991–94
Screening plantain and cooking banana for resistance to black sigatoka	—	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	—	UNB, NRI	Benin, Nigeria, UK	1989–94
Ecological studies on the introduced larger grain borer in stored maize and cassava and in the surrounding habitats	IFAD, SDC, BMZ	INIFAP, CP, CIMMYT, EAP, Univ. of Göttingen	Benin, Honduras, Mexico	1988–95
Aspergillus flavus prevalence, toxicity pattern, other studies	WI, BMZ	Texas A&M Univ.	Benin, USA	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
Biological control				
Mongo 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, Côte d'Ivoire, Gabon, Ghana, Guinea Conakry, Zaire, Nigeria, Sierra Leone	1987–93
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	IIBC, DFPV,	Benin, Morocco, Niger, Oman, UK	1990–92
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 geolographic 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	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/ODA	—	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–

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
Crop Management				
Humid forest systems				
Characterization and diagnosis of cassava-based systems	core, Univ. of Helsinki	Univ. of Helsinki	Nigeria	1989–
Strategic crop management studies	core	UI	Nigeria	1989–
Adoptability and adaptability of alley cropping	core, Ford Foundation	UI, NFOR, EEC	Nigeria	1986–1992
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
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	Winand Staring Centre	var. sites, W & C Africa	1990–
Strategic crop management studies	core	AUW, IMI, ILCA	var. sites, W & C Africa	1990–
INTERNATIONAL COOPERATION DIVISION				
NCRE Development of institutional capacity for research on cereals and facilities for transmitting research results to farmers	USAID	IRA	Cameroon	(Phase II) 1991–95
Ghana Grains Development Project 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	50 Sahelian countries	Burkina Faso	1986–92
SADCC Cowpea Research Project Development of cowpea production in SADCC 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	1986–92
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	1989–93

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
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, Guinea, Guinea-Bissau, Ghana, Mali, Nigeria, São Tome & Principe, Zaire	Nigeria	1990–92
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
Regional Research Project on Maize and Cassava. 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

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

Acronyms used in the inventory of research projects

ABU Ahmadu Bello University (Nigeria)
AFNETA Alley Farming Network for Tropical Africa
AGCD Administration generale de la cooperation au developpement (Belgium)
AIDAB Australian International Development Bureau
ANU Australian National University
AUW Agricultural University, Wageningen
BMZ Bundesministerium fur Zusammenarbeit (Germany)
CABI Commonwealth Agricultural Bureau International (UK)
CIAT Centro Internacional de Agricultura Tropical
CIDA Canadian International Development Agency
CIMMYT Centro Internacional de Mejoramiento de Maiz y Trigo
CP Colegio de Postgraduados (Mexico)
CRBP Collaborative Research on Bananas and Plantains (Cameroon)
CRI Crops Research Institute (Ghana)
CSIRO Commonwealth Scientific and Industrial Research Organization
DANIDA Danish International Development Agency
DFPV Department de formation en protection des vegetaux (Benin)
DGIS Directorate General for Development Cooperation (Netherlands)
EAP Escuela Agricola Panamericana (Honduras)
EEC European Economic Community
EMBRAPA Empresso Brasiliera de Pesquisa Agropecuaria
ESARRN East and Southern Africa Root Crops Research Network
ETH Eidgenossisch Technische Hochschule (Switzerland)
FAO Food and Agriculture Organization of the United Nations
FHIA Fundacion Hondureno de Investigacion Agricola (Honduras)
GGDP Ghana Grains Development Program
GTZ Gesellschaft fur Technische Zusammenarbeit (Germany)
IAR Institute for Agricultural Research, Samaru (Nigeria)
IARCS international agricultural research centers
IAR&T Institute of Agricultural Research and Training (Nigeria)
ICRAF International Center for Research in Agroforestry
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IDRC International Development Research Center
IER Institut d'economie 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 Investigacao Agronomico (Mozambique)
INIBAP International Network for the Improvement of Bananas and Plantains
INIFAP Instituto Nacional de Investigaciones Forestales y Agropecuarios (Mexico)
IRA Institut de la recherche agronomique (Cameroon)
IRRI International Rice Research Institute
ISF Institute of Soil Fertility (Netherlands)
KU Katholieke Universiteit Leuven
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 Biological Nitrogen Fixation Technologies for International Development (Hawaii)
NIFOR Nigerian Insitute for Oil Palm Research
NIHORT National Institute for Horticultural Research (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)
PASCON Pan-African Striga Control Network
RVAU Royal Veterinary and Agricultural University (Denmark)
SADCC Southern Africa Development Coordination Conference
SAFGRAD Semi-Arid Food Grains Research and Development Project
SDC Swiss Development Corporation
TSBF Tropical Soil Biology and Fertility Program
UC University of California
UI University of Ibadan
UNB Universite nationale du Benin
UNDP United Nations Development 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
WARDA West Africa Rice Development Association
WI Winrock International

IITA

STATEMENT OF FINANCIAL POSITION

31 December 1991

Expressed in US $ thousands

ASSETS	1991	1990
Cash and short-term deposits	10,196	8,644
Accounts receivable:		
Donors	6,968	7,862
Others	918	363
Inventories	1,107	2,544
Other assets	201	209
Property, plant and equipment	32,241 *	58,356
	51,631	77,978
LIABILITIES AND FUND BALANCES		
LIABILITIES		
Accounts payable and other liabilities	6,533	7,639
Accrued salaries and benefits	2,947	3,071
Payments in advance—donors	3,578	3,974
	13,058	14,684
FUND BALANCES		
Capital	32,241	58,356
Capital development	2,109	1,224
Operating	4,223	3,714
	51,631	77,978

Note:

* Prior to 1 January 1991, "Property, plant and equipment" was stated at acquisition cost and not depreciated. With effect from 1 January 1991, the CGIAR introduced depreciation accounting in order to comply with generally accepted accounting standards. Accumulated depreciation on assets held at 31 December 1990 has been deducted from the cost of fixed assets at 31 December 1991 and amounts to US$25.5 million. This together with movements during 1991 accounts for the decrease in the carrying value of assets between December 1990 and December 1991.

IITA

STATEMENT OF ACTIVITY

31 December 1991

Expressed in US $ thousands

REVENUE	1991	1990
Grants	34,274	35,333
Other income	306	613
	34,580	35,946
EXPENSES		
Research programs	21,072	21,694
Conferences and training	2,103	2,290
Information services	760	1,039
General administration	3,534	3,593
General operations	3,391	3,248
Property, plant and equipment expenditures	-*	3,054
Depreciation	3,466	-
Exchange (gains)/losses	(255)	380
Total expenses	34,071	35,298
Excess of revenue over expenses	509	648

Note:

* Expenditure on fixed assets during 1991 is accounted through the balance sheet, following introduction of the new depreciation policy.

IITA

STATEMENT OF CHANGES IN FINANCIAL POSITION

For the year ended
31 December 1991

Expressed in US $ thousands

SOURCES OF FUNDS	1991	1990
Excess of revenue over expenses	509	648
Depreciation (1990 net capital additions)	3,466	3,054
Disposal of assets	282	-
Decrease in accounts receivable—donors	894	196
Decrease in accounts receivable—other	-	140
Decrease in inventories	1,437	1,083
Decrease in other assets	8	-
Increase in accrued salaries and benefits	-	18
Increase in payments in advance—donors	-	509
	6,596	5,648
APPLICATION OF FUNDS		
Purchase of property, plant, and equipment	2,863	3,454
Increase in accounts receivable other	555	-
Increase in other assets	-	31
Decrease in accounts payable and other liabilities	1,106	455
Decrease in accrued salaries and benefits	124	-
Decrease in payments in advance—donors	396	-
	5,044	3,940
INCREASE IN FUNDS	1,552	1,708
CASH, BEGINNING OF YEAR	8,644	6,936
CASH, END OF YEAR	10,196	8,644

IITA

DONORS 1991

Expressed in US $ thousands

DONORS	Core Funding	Special Project Funding
African Development Bank	350	-
Austria	90	-
Belgium	1,007	785
Canada	1,752	156
China	10	-
Commission of the European Communities in Nigeria	107	1,047
Denmark	215	62
Finland	278	-
Ford Foundation	100	238
France	670	-
Germany	1,285	500
India	25	-
International Development Research Center	-	754
International Fund for Agricultural Development	-	401
Italy	723	404
Japan	2,901	-
Korea, Republic of	50	-
Netherlands	738	-
Nigeria	48	3
Norway	732	-
Rockefeller Foundation	379	198
Sweden	322	-
Switzerland	831	362
United Kingdom	796	-
United Nations Development Program	96	-
United States Agency for International Development	5,800	5,256
University of Hohenheim	-	191
World Bank	3,390	-
Other contributions (BCP & ICRAF)	-	1,523
Closed and miscellaneous projects	-	36
Total	22,695	11,916

PROFESSIONAL STAFF

Management division

Executive management
L. Brader, PhD, director general
S. A. Adetunji, PhD, special assistant to director general
J. Cramer, BA, executive assistant to director general
J. H. Davies, BSc, director, office of the director general [2]
J. P. Eckebil, PhD, deputy director general, international cooperation
K. S. Fischer, PhD, deputy director general, research [2]
S. K. Hahn, PhD, director emeritus
C. F. McDonald, MSc, assistant to director general, (for research)
W. Powell, BSc, deputy director general, management

Administrative and auxiliary services
C.A. Enahoro, manager, Ikeja guest house
B. Fadirepo, travel services manager
C. Inniss-Palmer, specialist english teacher
A. Jackson, deputy head, international school of IITA
N. Jackson, head, international school of IITA
G. McIntosh, CMA, head, internal audit
A. R. Middleton, BSc, manager, international house
R. I. Olorode, security manager
D. J. Sewell, manager, aircraft operations
O. Sholola, ACA, audit senior

Budget and finance
D. A. Governey, FCA, director
B. A. Adeola, FCIS, accountant
O. E. Adepoju, ACA, senior analyst, accounting procedures [2]
A. A. Akinbolo, BSc, senior technical analyst
C.A. Babalola, ACA, senior analyst, accounting procedures
P. O. Balogun, FCCA, finance manager
J. E. Bolorinwo, MBA, payroll accountant
P. Eluk, MBA, budget and planning coordinator
R. Obikudu, MBA, materials manager
S. J. Udoh, AMNIM, chief accountant

Computer services
L. J. McDonald, LLB, computer manager
N. N. Eguzozie, BSc, computer programmer
T. D. Oluyemi, MSc, computer programmer

Human resources
T. A. Akintewe, FRCP, (Edin.) head, medical services
J. O. Badoki, MBA, acting head, human resources
J. B. Elegbe, MSc, personnel manager
F. O. A. Osinupebi-Cole, MRCP (uk), physician
J. Thackway, MA, director, human resources [2]

Information services
S. M. A. Lawani, PhD, director
A. O. Adekunle, MSc, editor
R. O. Adeniran, MLS, principal librarian
A. A. Azubuike, MLS, principal librarian [2]
Y. Adedigba, MA, head, library services
J. I. Adeyomoye, MLS, principal librarian
K. Atkinson, MSc, head, publications
T. Babaleye, MCA, public information manager
D. Haastrup, MCA, public relations manager
D. R. Mohan Raj, PhD, science writer/editor
E. Nwulu, MSc, audiovisual specialist
B. O. Ojurongbe, BSc, production manager
T. T. Owoeye, MLS, editor
F. N. Ubogu, MLS, principal librarian [2]
R. Umelo, BA, editor

[1] Term ended during 1991

[2] Left during the year (1 April 1991–31 March 1992)

Physical plant services
A. Bhatnagar, head, physical plant services
J. G. H. Craig, director [2]
E. O. Akintokun, research vehicle officer
A. C. Butler, building and site services officer
L. I. Ojumo, telecommunications services officer
M. A. Oyedeji, electrical services officer
P. G. Gualinetti, construction site engineering services officer
D. A. Rosenzweig, heavy equipment and research vehicle services officer
S. W. Quader, electronic services officer

Commodity improvement division
M. Winslow, PhD, breeder, interim director

Grain legume improvement program
K. E. Dashiell, PhD, breeder (soybean), program leader
P. Q. Craufurd, PhD, crop physiologist
G. O. Myers, PhD, cowpea breeder
O. N. Nakayama, PhD, JICA expert (soybean postharvest scientist) [2]
H. O. Ogundipe, MSc, food technologist [2]
M. Osho, MSc, national coordinator, soybean utilization
B. B. Singh, PhD, cowpea breeder and officer-in-charge
S.R. Singh, entomologist, director [2]
I. Watanabe, PhD, TARC physiologist [2]
R. Aboidoo, MSc, NIFTAL associate expert

Root and tuber improvement program
R. Asiedu, PhD, plant breeder, program leader
M. Bokanga, PhD, biochemist
A. G. O. Dixon, PhD, breeder
I. J. Ekanayake, PhD, physiologist
S. Y. C. Ng, MSc, tissue culture specialist
Visiting scientist
K. V. Bai, PhD, cytogeneticist
Postdoctoral fellow
G. Eggleston, PhD, food technologist/biochemist [2]

Plantain and banana improvement program
D. R. Vuylsteke, Ir, agronomist (plantain), officer-in-charge
R. Ortiz, plantain and banana breeder

Rice research program
Postdoctoral fellow
R. C. Joshi, PhD, entomologist [2]

Maize research program
M. Winslow, PhD, breeder, program leader
S. K. Kim, PhD, breeder
J. Kling, PhD, breeder
J. H. Mareck, PhD, breeder [2]
Postdoctoral fellow
O. M. Olanyo, PhD, plant pathologist [2]
Visiting scientists
L. Everett, PhD, maize breeder [2]
S. N. C. Okonkwo, PhD, striga biologist [2]

Resource and crop management division
D. S. C. Spencer, agricultural economist, PhD, director

Resource management research program
M. J. Swift, PhD, ecologist, leader
A. N. Atta-Krah, PhD, coordinator, AFNETA
I. O. Akobundu, PhD, weed scientist
K. Dvorak, PhD, economist
M. Gichuru, PhD, agronomist (soil fertility)
S. S. Jagtap, PhD, agroclimatologist
B. T. Kang, PhD, soil fertility scientist
N. Sanginga, PhD, assistant coordinator, AFNETA
S. Hauser, PhD, soil physicist
B. Vanlauwe, BSc, junior expert

Crop management research program
A-M. N. Izac, PhD, natural resource economist
J. Smith, PhD, agricultural economist
E. Tucker, PhD, weed scientist
K. Mulongoy, PhD, soil microbiologist
H. J. W. Mutsaers, PhD, agronomist
G. K. Weber, PhD, agronomist
Postdoctoral fellows
A. M. Manyong, PhD, agricultural economist
Y. Mohamoud, PhD, agronomist
M. O. Musoko, PhD, soil microbiologist
R. A. Polson, PhD, agricultural economist [2]
Collaborative study of cassava in Africa (COSCA)
F. I. Nweke, PhD, agricultural economist and team leader
Y. C. Prudencio, PhD, regional coordinator [2]

Plant health management division
H. R. Herren, PhD, entomologist, director

Biological control program
P. Neuenschwander, PhD, entomologist, leader
J. S. Yaninek, PhD, entomologist
C. Gold, PhD, entomologist
C. J. Lomer, PhD, entomologist (IIBC)
B. Mégevand, MSc, mass rearing specialist

Host plant resistance program
N. A. Bosque-Pérez, PhD, entomologist, leader
D. Berner, PhD, striga biologist
A. E. Awad, PhD, striga biologist
D. A. Florini, PhD, plant pathologist
C. N. Akem, PhD, soybean pathologist
T. Mesfin, PhD, entomologist
L. E. N. Jackai PhD, entomologist [3]
F. Gauhl, PhD, plant pathologist
C. Pasberg-Gauhl, PhD, plant pathologist
H. W. Rossel, Ir, virologist

Habitat management program
M. Tamo, PhD, bioecologist
F. Schulthess, PhD, bioecologist
H. M. Dreyer, MSc, ecologist
K. F. Cardwell, PhD, plant pathologist

Technology transfer and training unit
M. E. Zweigert, Dipl. ing., regional coordinator (GTZ)
W. N. O. Hammond, PhD, entomologist
T. M. Haug, MSc, mass rearing specialist
A. Wodageneh, PhD, training officer, FAO
Visiting scientists
N.H.D. She, PhD, entomologist
L.K. Tanigoshi, PhD, acarologist [3]
Postdoctoral fellows
H. Bottenberg, PhD, entomologist
A. Paraïso, PhD, pathologist
T. G. Shanower, PhD, entomologist [2]
Associate experts
B. Kristensen, MSc, acarologist, (DANIDA)
C. Boavida, MSc, ecologist
H. M. Dreyer, MSc, entomologist

[2] *Left during the year (1 April 1991–31 March 1992)*
[3] *On Sabbatical*

Research support

Analytical services laboratory
J. L. Pleysier, PhD, head

Biometrics
P. Walker, MA, biometrician

Biotechnology research unit
G. Thottappilly, PhD, head [†]
S. R. Schnopp, PhD, biotechnologist
Visiting scientist
R. E. Ugborogho, PhD, biotechnologist
Postdoctoral fellow
D. H. Mignouno, PhD, biotechnologist

Genetic resources unit
N. Q. Ng, PhD, head
S. Padulosi, Dott, plant explorer

Research farms unit
D. C. Couper, MSc, head
P. D. Austin, BSc, research farms development officer
P. V. Hartley, BSc, farm management engineer

Postharvest unit
Y. W. Jeon, PhD, head
L. S. Halos, MS, research specialist

IITA Benin station
J. B. Akinwumi, MSc, engineer
J. N. Quaye, MA, leader, management unit and officer-in-charge
M. N. Versteeg, PhD, leader, technology transfer unit

IITA Cameroon station (Mbalmayo)
S. L. Claassen, MSc, farm manager
P. G. Gillman, PhD, officer-in-charge
N. R. Hulugalle, PhD, soil physicist [†]
Postdoctoral fellows
N. W. Menzies, PhD, soil chemist
D. Russell, PhD, anthropologist/Rockefeller fellow

Collaborating scientists from other centers
K. Alluri, PhD, liaison scientist, IRRI/INGER Africa
D. Ladipo, PhD, ICRAF scientist
M. C. Porto, PhD, CIAT/IITA cassava scientist
B. N. Singh, PhD, breeder (WARDA)

International cooperation and training division

J. P. Eckerbil, PhD, deputy director general

International cooperation
J. B. Abaka-Whyte, PhD, research liaison scientist
E. F. Degonus, BSc, project development coordinator
O. M. Ogunyinka, MSc, coordinator, monitoring and evaluation
J. B. Suh, PhD, research liaison scientist
A. P. Uriyo, PhD, project development coordinator

Training program
H. Gasser, PhD, director
A. A. Adekunle, MSc, research training specialist
M. Ajoyi, 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
R. Zachmann, PhD, materials specialist

Interpretation and translation unit
E. Molinero, head, interpretation/translation
B. Auvord, interpreter/translator [†]
O. B. Hounvou, interpreter/translator
C. Lord, interpreter/translator
V. Pousse, translator
F. B. Sall, interpreter/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, extension agronomist
J. Delongnon, PhD, grain legume specialist
H. C. Ezumah, PhD, farming systems agronomist
M. Kamuanga, PhD, agricultural economist
D. McHugh, MSc, socioeconomist
M. Moussie, PhD, agricultural economist/coordinator
A. O. Osiname, PhD, farming systems agronomist
J. A. Paku, 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
J. M. Fajemisin, PhD, pathologist/breeder, project leader and maize network coordinator
N. Muleba, PhD, agronomist, coordinator cowpea network

USAID/IITA applied agricultural research (RAV) project, Zaire
F. E. Brockman, PhD, chief of party and agronomist [*]

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 (legume)
O.O. Okoli, PhD, breeder (root crops)

EEC/IITA/SADCC cowpea project
R. Amable, PhD, cowpea agronomist
A. L. Dalo, PhD, cowpea breeder
J. D. Naik, PhD, legume pathologist

[†] Left during the year (1 April 1991–31 March 1992)
[*] On Sabbatical

PUBLICATIONS BY IITA STAFF

Contributions by IITA staff to scientific literature that become available during 1991, including journal articles, papers in monographs or conference proceedings, and edited monographs.

Afun, J. V. K., L. E. N. Jackai, and C. J. Hodgson. 1991.
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Bationo, A., B. J. Ndunguru, B. R. Ntare, C. B. Christianson, and A. U. Mokwunye. 1991.
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Bemer, D. K., G. T. Berggren, and J. P. Snow. 1991.
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Detail of mosaic mural outside the entrance to the IITA International House at Ibadan, which depicts farmers with IITA mandate crops and which was created to mark IITA's 25th anniversary.

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