Consultative Group on International Agricultural Research
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Preface

Productive agriculture is both an economic and a humanitarian imperative in the developing world. The rural sector must generate savings and production to move development forward. It must also overcome the hunger and malnutrition that are the familiar lot of poor people everywhere.

In many developing countries, the rural sector is commonly not only the largest but also the most depressed part of society. It provides too little employment and too little production to raise living standards and prepare the way for further advance.

The world food situation continues to be precarious. Over 450 million people live on the edge of starvation. Throughout the world, another thousand million people subsist on substandard diets.

This state of affairs must and can be changed. The world can feed itself. The basic problems affecting food supply result from decisions made by governments and by individuals, not from uncontrollable or irresistible forces of nature. Solutions lie in new policies and new actions.

The necessary resources already exist or can be found. To mobilize them, however, requires acts of international cooperation and national initiative on an unprecedented scale—for example, in investment, trade, education, health, and technology. It is plain that the highest priority must be given to achieving a marked increase of food production in the less-developed countries themselves.

An essential contribution to this objective is being made by the Consultative Group on International Agricultural Research (CGIAR). The group is sponsored by the Food and Agriculture Organization of the United Nations, the World Bank, and the United Nations Development Programme, and comprises in all some 45 countries, international and regional organizations, and private foundations. The group today supports 13 international agricultural research institutions, funds for which are provided by 35 contributing members. The purpose of the group is to bring the resources of modern biological and socioeconomic research to bear on the long-neglected possibilities of agricultural progress in the tropics and subtropics, where nearly all the less-developed countries lie. The research and training programs undertaken by the centers and sponsored by the group seek to arm the developing countries with superior varieties of essential crops and improved farming systems for the production of food plants and animals.

Recently, the CGIAR was awarded the King Baudouin International Development Prize for having made a significant contribution to the development of the Third World and to the solidarity and good relations between the industrialized countries and the countries in process of development. This recognizes the importance of the scientific work of the research institutions and the support it has received from the international community.
This booklet describes the activities of the group and the international research and training system it sponsors. It is intended to be useful to policymakers, specialists, and interested laymen—both those who may find ways to benefit from the system's activities and those who may find ways to contribute to its continued success.

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CGIAR and
The International
Research Network
The Consultative Group on International Agricultural Research (CGIAR), established in 1971, is an informal association of governments, international and regional organizations, and private foundations, dedicated to supporting a system of agricultural research centers and programs around the world. The purpose of the research effort is to improve the quantity and quality of food production and the standard of living of poor people in the developing countries. More than 7,000 staff members, including some 600 senior scientists from more than 40 developed and developing countries, work at CGIAR-supported centers on crops, livestock, and farming systems that yield three-quarters of the developing countries' total food supply.

THE WORLD FOOD PROBLEM

By 1980, total food production in the developing world was growing slightly faster than population; per capita production was about 5 percent higher than it had been in 1960. Such aggregate statistics, however, mask severe food deficits in many countries; persistent low productivity of many major food crops; problems and inequities in food distribution; and the plight of particular population groups.

Some 300 million poor people in sub-Saharan Africa and parts of Latin America subsist on roots, tubers, and coarse grains, which have not shared the recent production gains of the major cereals. In Asia, where a billion people depend on an annual rice harvest of approximately 250 million tons, overall production has barely kept up with demand, and annual production in the poorest areas has increased by only 2.4 percent since 1960. Outside of India, food self-sufficiency in the poorer countries as a whole has actually declined slightly in recent years.

As a result, many developing countries of the world have become net grain importers. Cereal deficits in Asia, Africa, and Latin America—all net grain exporters before World War II—are currently almost 60 million metric tons and will continue to rise.

Neither commercial market systems nor the costly food-distribution programs subsidized by many governments offer much help to the majority of the world’s poor and malnourished, who remain in the subsistence-farming areas of East and South Asia, sub-Saharan Africa, and parts of Latin America. In many of these areas, growing populations strain inadequate soil and water resources to produce a bare living. Even worse off, and most difficult of all to help, are the increasing numbers of rural people—perhaps as much as one-third of the total rural population—who have no land at all.

It is clear that chronic malnutrition and hunger are linked to more general problems of poverty, inequitable distribution of land and other assets, underdevelopment, and adverse agroclimatic conditions. Central to the alleviation of these problems must be a significant increase in food production in the developing countries, especially in the areas of small farms and resource-poor farmers.

For most of the millennia since the inception of agriculture, increased food production has been gained mainly by the expansion of cultivation to seemingly inexhaustible virgin lands. Today, however, it is clear that the additional production needed in the developing countries cannot
In the developing countries of the tropics and subtropics, however, where many of the major food crops originated, typical yields remain only a fraction of those in the temperate zones. In the late 1970s, rice yields in the developing countries averaged less than two tons per hectare, compared with 5.5 tons per hectare in developed countries. Similarly, a yield gap exists for all other major food crops. Such disparities are a measure both of the developing countries' predicament and of the gains that might result from research.

PROBLEMS OF TROPICAL AGRICULTURE

The yield disadvantage of the tropical and subtropical countries cannot be overcome simply by transferring technologies from the temperate zone. The typical developing-country farmer faces problems and constraints for which temperate-zone solutions are often inappropriate and ineffective. The developing-country farmer, for example, typically tills fewer than five hectares; fewer than three in much of Asia; fewer than two in Bangladesh. What soil he has may be low in fertility and poor in structure; he is likely to have too little water or too much, and at the wrong time. The tropical heat bakes his soil, enervates his seeds, and withers his plants.

His seed is usually a traditional local variety, saved from the previous harvest. Its great virtue is its ability to yield modestly but dependably under difficult conditions with rudimentary management. However, it lacks the genetic potential to reward fertilizer, water, and care with increased yields. Even if the farmer has access to fertilizers and other inputs, he may not have the cash or the credit to buy them, the information to use them to advantage, or the equipment to apply them. Even if he manages to produce a surplus, he may lack access to markets at prices that will repay his investments.

AGRICULTURAL RESEARCH: THE CENTER CONCEPT

The international centers supported by the Consultative Group on Interna-
tional Agricultural Research develop improved crop varieties and farming systems to increase food production in the developing countries and improve the lot of poor farmers. The present system of internationally funded centers located in the developing countries has its roots in a joint, crop-improvement program undertaken in 1941 by the Mexican government and The Rockefeller Foundation. A team of Mexican and United States scientists, combining several agricultural specialties, made a systematic effort to develop superior varieties of maize and wheat. By 1948, thanks to favorable weather and improved crop varieties, including wheats that were able to resist a severe rust epidemic, Mexico did not have to import grain for the first time in 35 years.

The most significant products of the Mexican program were the semi-dwarf wheats—short, stiff-strawed varieties that did not topple as they responded to fertilizer and irrigation with grain-heavy heads. Insensitive to day length, the improved wheats were adapted to subtropical as well as temperate latitudes. By 1967, Mexican wheat yields had trebled, and the Mexican varieties were on their way around the world.

Meanwhile, in 1959, encouraged by the progress in Mexico, the Rockefeller and Ford foundations joined forces to establish the first truly international agricultural research center, the International Rice Research Institute (IRRI), with an independent board of trustees and a scientific staff recruited from around the world. IRRI started work early in 1962 at Los Baños, in the Philippines, with a half-dozen senior scientists from as many countries. Their goal was to build an ideal tropical rice plant: short and stiff-strawed, insensitive to day length; with narrow, erect leaves to capture solar radiation and permit dense planting, and seed dormancy at harvest-time to prevent untimely sprouting; early maturing to permit multiple cropping and to avoid pests and diseases; and inherently resistant to major diseases.

Beginning with IR-8 in 1966, IRRI's improved varieties spread rapidly over the irrigated rice lands of Asia, adding $300 million to the value of the annual harvest by 1968. The total investment until then in IRRI's physical plant and research was only...
$15 million. Ten years later, dwarf rices were planted on some 25 million hectares, about one-quarter of Asia's rice area. With Mexican wheats growing on some 29 million hectares worldwide, the increased yields from the improved varieties produced by international research were feeding some 300 million people.

The Mexican crop programs were reconstituted in 1966 on the IRRI model as the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), under joint Ford and Rockefeller foundation sponsorship. The following year, the foundations established two more international centers, concerned with the crops and farming systems of the African humid tropics and the lowland tropics of the Western Hemisphere.

The international research centers themselves constitute an important new approach to increasing food production in developing countries. Independent and autonomous, responsible to boards of trustees selected from the world's distinguished agricultural scientists and policymakers, the centers can pursue long-range research goals with fewer of the staffing and funding constraints and the political pressures common in national institutions. Widely recognized for scientific excellence and worthy purpose, the centers attract talented, dedicated scientists from all over the world interested in finding practical solutions to the world's food problems. The centers cut across traditional academic lines to form multidisciplinary teams of diverse specialists for the improvement of major crops and farming systems, supported by research resources not available in most national programs. With worldwide germplasm collections and international networks for testing and adapting new materials, the centers can provide a rapid flow of technologies to national programs.

The international centers also serve as unique training institutions to strengthen the capacities of developing countries to carry out their own research, as well as to collaborate with the centers in developing, testing, and adapting new technologies. Most of the several hundred trainees who come to the centers each year spend 3 to 12 months working under the guidance of senior staff scientists and training specialists in the fields and laboratories—a novel experience for many agricultural graduates from developing countries, where academic training often does not include practical experience in actual farming or production research. The purpose of the in-service training is to produce the well-prepared, dedicated researchers and other specialists sorely needed in the developing countries. The centers also afford research opportunities to M.S. and Ph.D. candidates, postdoctoral fellows, and visiting scientists whose projects are relevant to the centers' primary mission.

The CGIAR

By the late 1960's, many governments and international funding agencies felt that
support for the existing international centers should be increased, and that the system should be expanded to cover other food crops, farming systems, and agro-climatic zones of the developing world. At the same time, it was evident that the Rockefeller and Ford foundations, by then each contributing some $3 million to the four existing centers, could not long continue as the sole supporters of the system or undertake its expansion.

At four meetings during 1969 and 1970, the leaders of the major national and international funding agencies reviewed the opportunities for cooperation in increasing food production in developing countries. In October 1969, the president of the World Bank proposed to the United Nations Development Programme and the Food and Agriculture Organization that the three institutions jointly organize long-term support for an expanded international agricultural research system.

The result of these initiatives was the establishment in 1971 of the Consultative Group on International Agricultural Research, under the joint sponsorship of the World Bank, the UNDP, and the FAO. The Bank provides the CGIAR with its chairman and secretariat, while the FAO provides a separate secretariat for the group's Technical Advisory Committee (TAC). The TAC is made up of 13 distinguished agricultural and social scientists, nominated by the three co-sponsors and approved by the CGIAR members, and drawn approximately equally from the developed and the developing countries. The TAC regularly reviews the scientific and technical aspects of all center programs and advises the Consultative Group on emergent needs, priorities, and opportunities for research.

Like the international centers, the Consultative Group is an unconventional institution. It operates without any legal charter, written rules, protocols, or bylaws, entirely by the common consent, shared interest, and goodwill of its members. Meetings, held once or twice yearly to consider program and budget proposals, policy issues, and other matters from the centers, are informal and collegial. Decisions are reached by consensus; donations are on a voluntary, bilateral basis between individual members and centers. The CGIAR, while it is active in coordinating and stimulating financial support for the system, does not itself actually grant funds.

The CGIAR tries to maintain a delicate balance between informality and the need for accountability to assure the efficient and effective use of large amounts of money in a flexible, decentralized system. Each center prepares an annual program in the areas where food needs are greatest, as in Asia and the Middle East, for example, 80 percent of arable land is already being cultivated. Increases in food production must, therefore, come from increased output per unit area.
and budget paper according to broad guidelines proposed by the CGIAR. The papers are reviewed by the CGIAR Secretariat and the TAC with the center directors before being submitted with comments to the Consultative Group for approval and funding by its members. In addition, more comprehensive quinquennial reviews are made of the programs of each center. The CGIAR itself is committed to an annual review and year-by-year extension of its five-year program, as well as to a quinquennial review covering the entire international research system, undertaken for the first time in 1976.

The CGIAR began operation in 1972 with 15 donor members providing $20 million to support the four original international centers. By 1980, the donor members had increased to 35 countries, international and regional agencies, and private foundations, contributing $120 million to 13 centers and activities. Any organization, public or private, planning regularly to contribute significant amounts to some of the centers and programs supported by the CGIAR may become a donor member. In addition to the donors, CGIAR members include 10 developing countries, elected by the FAO regional caucuses to represent the views of the five regions of the developing world.
duction and distribution to evaluate alternative policies and strategies for increasing food production in developing countries. The International Board for Plant Genetic Resources promotes the conservation and analysis of germplasm of important food species for use in breeding programs.

The International Service for National Agricultural Research was established in 1960 to assist developing countries in strengthening their domestic agricultural research capabilities. In response to requests for assistance from developing countries, the service’s goal is to increase the competence of national programs to plan, organize, and execute agricultural research and development, and to collaborate effectively with the international centers in the testing and adaptation of new technologies.

From their inception, the international centers have depended on close formal and informal ties with networks of national programs. Many of the professionals now staffing national programs in the developing countries are graduates of the centers’ training programs. A significant trend in the recent development of the centers has been the extension of their activities from their headquarters campuses to other developing countries. By 1980, more than 110 scientists from the international centers—almost 20 percent of the total senior staff—were working directly with national and regional programs in more than 40 developing countries. In the long term, however, the international centers cannot supply scientific personnel to compensate for the inadequate staffing and support of many national programs without undermining both their own primary research mission and the self-reliance of the developing countries.

While the initial, urgent concern of the international centers has been to increase overall food production in the developing countries, the CGIAR has become increasingly mindful that the high-yielding varieties that have dramatically increased total yields have not yet materially helped the great majority of resource-poor farmers. The group has accordingly placed increased emphasis on the development by the international centers of new technologies suited to the farmer who lacks access to good soil, purchased inputs, irrigation, and other resources. The emerging generations of improved varieties, genetically endowed with drought tolerance, resistance to major pests and diseases, and the ability to yield well with fewer inputs, will be of special benefit to resource-poor farmers.

With increased concern for the resource-poor farmer has come the need for understanding the diverse traditional farming systems that have evolved to fit his circumstances. Increased farming-systems research at the international centers has engendered sociological and economic studies to identify the motives for farmers’ behavior and the factors in-

Gains from increased food production benefit those who consume food as well as those who produce it. Low-income consumers generally spend more than 80 percent of their income on food.
fluenting his adoption of new methods, and to monitor the effects of new technologies.

THE FUTURE OF THE CGIAR SYSTEM

The members of the CGIAR are committed to an enterprise that is inherently and inescapably long term. Some of the centers' early undertakings are only now bearing fruit; some of the latest will not even be in full operation until the 1990's. Evaluations of the CGIAR system and the international-center concept must therefore rely heavily on the decade or more of experience with high-yielding varieties of wheat and rice.

The available data indicate that where conditions are favorable, and fertilizer and irrigation are available, the great increases in food production due to the high-yielding varieties are accompanied by improvements in income, employment, and nutrition. Neither farm size nor form of land tenure significantly affects the adoption of improved varieties, which are accepted approximately equally by both large and small farmers, landlords, and tenants. Among consumers, low-income groups are the greatest gainers from the lowered food prices resulting from increased supplies. Income gains among farmers are directly proportional to farm size. Although there is general agreement that new varieties have resulted in increased labor use per hectare, the principal impact on employment is not on farm employment. Additional income generated by new varieties stimulates nonagricultural as well as agricultural employment. Nutritionally, according to studies in India, the high-yielding varieties have increased the total production of protein and food energy by at least 20 percent, despite the displacement of high-protein pulses by the improved cereals.

The high-yielding varieties are grown on more than one-third of the total wheat and rice lands in the developing world—a total of 55 million hectares, equal to the total cereal-growing area of Central and South America—and their extent continues to increase by some 4.5 million hectares per year. In the case of high-yielding rice, the annual economic rate of return on the investment in IRRI has been estimated at about 80 percent.

At the CGIAR's annual meeting in 1979, the members endorsed a plan doubling the resources devoted to international agricultural research over the next five years. The plan contemplates a modest increase in the real level of funding for the established centers while enabling the newer centers to grow to their intended size. It also provides for the possibility of expanding the system into a few new research areas of special importance and promise.
The Centro Internacional de Agricultura Tropical has as its mandated primary concern the general welfare of poor urban and rural food consumers in a vast and diverse region: the tropics of the Western Hemisphere. This fundamental concern is expressed in CIAT's efforts to increase production of the region's four principal food commodities in the region—common beans, cassava, rice, and beef. In addition, CIAT collaborates significantly with CIMMYT on maize in the Andean region and a seed unit in support of the center's commodity programs and production activities in the hemisphere. Working closely with national programs throughout Latin America, CIAT develops improved crops and production systems that are appropriate to the actual ecological and economic conditions of the region's farmers.

CIAT's region includes high-elevation plateaus with good farmland and growing conditions; harsh Andean slopes; infertile lowland plains subject to alternating droughts and floods; rich river valleys and marshy deltas; and dense, multistoried rain forests. The social and economic conditions of the region's people are at least as diverse as their agroclimatic circumstances. To be useful, therefore, CIAT's research must be equally diverse, versatile, and responsive to both social and biological realities. The challenge is all the greater because only limited production-oriented research has been done in the past on many of the region's major environments and food commodities.

Throughout the region, most food crops are produced on small, subsistence farms. Cautious, poor farmers tend to rely on traditional crop varieties and production practices that require few inputs and mainly family labor or animal power to produce low but stable yields. Meat production, depressed by poor animal health and nutrition, offers farmers few incentives and is increasing only slowly. Meanwhile, the region's human population is increasing at an annual rate of nearly 3 percent, one of the highest in the world.

CIAT's efforts to increase food production are carried out throughout the Latin American tropics. The center's headquarters is a 522-hectare farm near Cali, Colombia. At Santander de Quilichao, just south of the headquarters, germplasm is screened and evaluated in soils of low fertility before advanced testing at other locations. New technologies for tropical pastures and cassava cultivation are tested at a savannah site at Carimagua, on the eastern plains of Colombia. CIAT researchers work closely with Brazilian colleagues on pasture problems at the Cerrado Center station near Brasilia. Many other cooperative research efforts involve CIAT closely with national programs throughout Latin America, with cassava research in Asia, and bean research in eastern Africa.

BEAN PROGRAM

One-third of the world's supply of Phaseolus vulgaris—the common, or dry, bean—is produced in Latin America. Eighty percent of the beans are grown by small farmers, often in association with other crops, such as maize or cassava. Beans are a crucial protein source for the low-income people who rarely have meat, but bean production in Latin America in recent years has increased at an annual rate of only 0.27 percent, far below the 3 percent annual population growth rate,
resulting in higher prices for beans and, in many countries, a marked decrease in per capita bean consumption.

Actual bean yields in Latin America are only one-third or less of the potential yields from available commercial varieties. Yields are depressed by a number of factors, including severe losses to pests and diseases. As a high-risk crop for poor farmers, beans are often cultivated on poor soils with inadequate rainfall, where yield potential is severely limited.

CIAT's Bean Program has assembled more than 20,000 accessions into a world germplasm bank for the species. Breeders

Breeding a better bean variety requires an interdisciplinary approach involving selection for resistance to diseases and pests, drought tolerance, nitrogen fixation ability, tolerance to adverse soils, and consumer preferences.

have evaluated thousands of lines for dozens of desired characteristics in a search for genes that will increase yields. They have already identified genotypes of the bean, a legume, that more effectively fix atmospheric nitrogen, thus potentially reducing fertilizer requirements. Other bean lines developed at CIAT perform well in low-phosphorus soils. CIAT scientists also have identified sources of genetic resistance to common mosaic virus, one of the most widespread and devastating bean diseases. This resistance is now included in all lines in the center's international testing program.

The search for inherent resistance to pests and diseases has now been extended from the existing genotypes in the germplasm collection to new, advanced lines bred at CIAT. International networks of cooperating programs evaluate CIAT's improved materials for effective resistance and yield in a variety of actual farming environments, leading to the selection of superior lines for release by many countries in the region.

CASSAVA PROGRAM

The root of the cassava, a plant native to tropical America, has become the third most important energy food for some 400 million people in the tropical world. Forty percent of the world crop is grown in Africa; the rest is divided equally between Latin America and Asia. Most cassava is
grown on poor soils by small farmers who lack access to fertilizer and other inputs. Even under these conditions, however, cassava has the potential to grow well and to provide an efficient, cheap source of carbohydrate calories for low-income rural and urban consumers.

The available evidence suggests that even with modest use of fertilizer, per hectare cassava yields average three to four tons of dry matter per year, which currently could be doubled or tripled relatively easily. Such yield increases will require genetically improved varieties with resistance to pests and disease and im-
Where possible, the centers coordinate their activities to accelerate research results. Here an IRRI-bred rice variety is evaluated at CIAT for suitability in a Latin American rice trial program.

proved production practices. New technologies for storing the bulky, perishable cassava tuber, and alternative end uses for surplus production, would help to stabilize market prices, increasing the incentive for farmers to produce more. Utilization, processing, and market research related to these needs is now in progress.

Using CIAT’s extensive collection of cassava germplasm, breeders are working toward superior cassava genotypes. At the rate of one generation per year, however, four to six years are required before the improved offspring of promising parents is ready for international distribution for field testing. In regional trials in several locations in Colombia over the last four years, CIAT’s new hybrids were yielding about nine tons of root dry matter per hectare—62 percent more than the best local materials and 140 percent more than the national average.

While improved cassava varieties are being developed and tested, improvements in cassava agronomy promise early production increases. CIAT scientists from a variety of disciplines are investigating both chemical and biological controls for important cassava pests, establishing optimum planting densities and efficient fertilizer levels, and designing procedures to protect planting materials from infection by pathogens. The CIAT cassava program is also developing practical, low-cost techniques for storing fresh tubers on the farm.

TROPICAL PASTURE PROGRAM

Some 850 million hectares of acid, infertile soils, more than half the land area of tropical Latin America, are unsuited to arable agriculture without massive inputs but adequate for producing beef, a major source of protein for the almost 400 million people of the region. Two-thirds of the beef in Latin America is produced in the tropics; per capita beef consumption in the region is almost equal to that of Western Europe. But beef productivity in tropical Latin America is only 25 percent as high as in the United States and Canada, and 50 percent as high as in the temperate zones of South America. Meanwhile, the demand is growing almost twice as fast as the supply.

Increased beef production is limited by the lack of good forage in the vast tropical savannahs and jungles, due to the high acidity and low fertility of the soils, high levels of aluminum and manganese, and seasonal water scarcity. Poor cattle nutrition is manifested in low rates of reproduction, diseases, and slow weight gain.

CIAT’s Tropical Pastures Program is evaluating more than 5,000 forage accessions from the region, searching for tolerance for problem soils combined with high yield and nutritional values. When desired characteristics do not appear together in existing varieties, they are combined in new lines by CIAT plant breeders. At the same time, soil microbiologists at the center are evaluating potentially superior associations of *Rhizobia* bacteria with forage legumes to improve the fertility of pasture soils and the protein content of forages. Agronomists are developing low-cost techniques, such as low-density
seeding, for establishing and maintaining improved pastures.

RICE PROGRAM

Rice is one of the most widely cultivated crops in Latin America. Production is evenly divided between irrigated and upland types. About two-thirds of the 2.8 percent average annual production increase in recent years has been due to expansion of rice cultivation; only one-third has come from increased yields. In countries where irrigated rice is predominant, dramatic yield increases have been experienced since the introduction of new varieties developed at CIAT and IRRI.

In collaboration with IRRI's International Rice Testing Program, CIAT collects materials from its own breeding program, from national programs in the region, and from IRRI for testing and evaluation under local conditions throughout tropical Latin America. CIAT's rice scientists also develop improved rice-farming systems adapted to the region's social and agroclimatic conditions, and screen new varieties for resistance to important pests and pathogens, especially rice blast disease, which is epidemic in the region. CIAT's long-standing cooperative breeding program with the Colombian Agricultural Institute (ICA) has resulted in several improved semi-dwarf varieties that have been successfully adopted throughout Latin America. CIAT is placing increased emphasis on extending to upland rice the improvements that have already been made in irrigated rice.
The Centro Internacional de la Papa (CIP) was established in 1971 near Lima, Peru. Its location in the ancestral homeland of the white, or Irish, potato—the tuber-bearing species of *Solanum*—affords the center access to a great variety of natural potato genotypes, and to the environments in which the species arose and to which it is naturally adapted. One of CIP's major aims is to improve the potato in its high-altitude temperate homeland in the Andes and to develop varieties for the lower tropical regions, where it has great potential as a low-cost, nutritious food for many areas of the developing world.

Compared with other food crops, the potato is rich in both total calories and proteins. It is also a good source of important vitamins—especially C and B—and minerals. As an economic crop, it is superior to most in food production per hectare and per day. Among major tropical crops, only the sweet potato ranks higher in total energy production per hectare per day; none ranks higher in protein production. Moreover, the potato matures in a shorter period than most tropical crops; it can fit into a variety of cropping systems.

Worldwide, with all its advantages, the potato is the fourth most important food crop, after wheat, rice, and maize. After languishing as a botanical curiosity for a century following its introduction into Europe in 1570, the potato became a major food, especially for the peasantry and the working class, as well as a major cattle feed during the 18th and 19th centuries. To a lesser extent, it also became a staple in North America.

In most developing countries, the potato is a luxury food, and is a staple food crop only in its native Andean range in Bolivia, Colombia, Ecuador, and Peru, where much of the arable land is at elevations of 10,000 feet and above and in the hill country of Nepal, Kenya, and Rwanda. The potato is one of the few food crops that produce well at high elevations. In all, of the 22 million hectares in the world planted to potatoes, only about 11 percent are in the developing countries. Only one developing country, India, is among the 10 major potato-producing nations, but it is worth noting that the People's Republic of China has an additional 5 million hectares in potato production, particularly in the southern hilly regions, and generally uses varieties that were imported from Europe and North America more than 50 years ago. The potato's retrograde progress in the tropical developing countries is due to the major liabilities of traditional cultivars, well adapted to temperate-zone conditions, under the very different conditions of the lowland tropics and subtropics. In hot, humid climates, pests and diseases are extremely severe problems, especially in areas where farmers cannot afford or obtain chemical pesticides. Tropical rainstorms leach natural nutrients and fertilizers out of the soil. Competition from weeds is intense. Available varieties are poorly adapted to the agroclimatic conditions and the agronomic systems of the tropics. The net result is that potato yields in the lowland tropics of Africa, Asia, and Latin America average less than half those in the temperate regions of Europe and North America. Moreover, under tropical conditions, harvested potatoes are susceptible to rot in storage. However, the most important problem is that the multiplication and distribution of tuber seed, the standard method of potato propagation,
are difficult and expensive in developing countries even in areas that are suitable for potato production with existing varieties.

THE POTATO'S POTENTIAL

In building a better potato for the tropics, CIP can take advantage of the fact that the temperate-zone varieties represent only a small fraction of the genetic resources of the species. CIP has established a world collection of potato germplasm, maintained in viable condition by annual replanting. The collection currently numbers some 15,000 genotypes, mostly from the Andean region, including its tropical parts where the genetic diversity of the species is greatest, but also including strains collected on expeditions throughout Central and South America. As a basis for further improvement of potato genotypes, CIP is converting the materials in its world collection from tuber seed to true, botanical seed, which can be stored almost indefinitely, remaining viable without annual replantings. Screened for potentially useful characteristics and catalogued in a computer for ready retrieval, the collection offers scientists from CIP and other institutions a rich assortment of genetic materials for the development of cultivars adapted to developing-world conditions. Samples of promising materials from the CIP germplasm bank are regularly sent to scientists in cooperating national programs and other organizations around the world.

While continuing research on techniques for faster, cheaper potato propagation by tuber seed, CIP is also increasing its interest in the use of botanical seed by farmers. Tuber seed represents more than half the cost of a potato crop in the tropics; true seed, which is easier to multiply, store, and distribute, and which can be held over like grain without losing viability, represents only 3 percent of the farmer's cost. True seed is also the only practical and efficient means for the breeding and propagation of improved varieties because 10 generations of careful cloning are usually required to produce enough tuber seed of a new variety to have a significant effect on production.

ACTIVITIES AND ACHIEVEMENTS

CIP's breeding program is producing improved potato genotypes that are insensitive to day length; tolerant of such environmental stresses as heat, cold, drought, and soil salinity; high in energy content; and capable of high yields under the various agroclimatic and agronomic regimes that are typical of the lowland tropics.

Resistance to the pests and diseases that attack potatoes in the tropics is a prime requisite in improved varieties. Breeding lines at CIP are screened for resistance to a number of fungal diseases: late blight and bacterial wilt are commonly associated, constituting a major impediment to potato production in the tropics. Combined resistance is now incorporated in CIP varieties.

Among the 20 known virus diseases of the potato, the two that significantly affect production—potato virus Y and potato leaf roll virus—have received the most attention at CIP. Good resistance to virtually all major viruses is now available and in the process of incorporation into national breeding populations.

CIP researchers are also screening germplasm for resistance to the insect vectors that transmit viral diseases. The prin-

Two tons of tubers are required to plant one hectare of potatoes. The woman is holding a jar containing the equivalent in true seed.
Principal vectors are the green peach aphid and the potato aphid; others include leafhoppers, leaf miners, potato tuberworm moths, and weevils. On certain hybrid potato plants, CIP researchers have noted glandular foliar hairs with sticky tips that trap insects—mainly aphids, but also flea beetles and mites—reducing epidemic infestations.

For the control of nematodes, which are important potato pests in many areas in the tropics, CIP researchers screen materials from the germplasm collection for resistance and tolerance. Fungus infection of cyst nematode females and eggs suggests the possibility of effective biological control.

For the lowland tropics, where long exposure to high temperatures and humidity limits potato production, CIP researchers have developed cultivars that mature in 60 days. Cold-climate varieties that mature in 100 days, compared with 150 to 180 days for traditional Andean varieties, are being bred to beat the onset of early frost at high elevations.

CIP's postharvest management program has developed small-scale community dehydration units that can be built from readily available materials in local machine shops for only U.S.$3,000 and can process a ton of potatoes per day. Simple, locally built storage facilities, using indirect light instead of refrigeration to control sprouting of seed potatoes during storage, have been developed to keep tubers for up to six months under highland conditions and for as long as four months in the lowland tropics.

Working in cooperation with national programs and other institutions, CIP's research is having significant effects on potato cultivation and production. In Peru, the potato has been introduced into high jungle areas, using varieties and farming methods developed at the center. Brown-rot resistance has resulted in the removal from quarantine of large areas of the country where the potato is a basic food. Yield increases of 15 to 35 percent are anticipated from Colombian varieties freed of viral disease at CIP. In Chile, CIP's assistance in redeveloping the national seed program has led to increases of two tons per hectare in commercial potato production. The two principal potato varieties cultivated in Costa Rica were developed in CIP's late-blight program. Guatemala has released five varieties from the late-blight program. Similar kinds of practical results have been seen in Nepal, the Philippines, and Rwanda.

These successes that have arisen from national research programs have great significance for CIP's own research objectives. The transference of the results of CIP's research in Peru and in other research sites around the world to farmers in developing countries depends on the ability of national research programs to absorb, adapt, and improve those results and to distribute them to farmers. For that reason, CIP has given high priority to supporting and collaborating with national research programs in those countries where the potato has the potential to be an important food crop. The single most important objective of these joint efforts is to develop seed production capability, as has been done in Turkey and in Tunisia, so that there exists the necessary vehicle for converting research into production and benefits for the farmers and consumers in developing countries.

In transferring its technology to the region, CIP works with national scientists as the technology is being adapted to local conditions so that the scientists can continue the transfer throughout the region.
The Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) grew out of a collaborative program between the Mexican government and The Rockefeller Foundation. The program, established in 1943, expanded into an international institute in 1966. CIMMYT works with scientists and national programs around the world on the improvement of maize, wheat, barley, and triticale.

All told, cereals make up over half of the world's diet. Maize and wheat—plus barley, on which CIMMYT also works—account for 60 percent of the global cereal harvest; they are grown on more than half the cultivated land in developing countries, where they are the major sources of carbohydrate and protein. Wheat is first among the world's food crops: the staff of life throughout the Middle East, North Africa, and the Indian subcontinent; and a secondary staple and an important commercial crop in Latin America. Worldwide, some 440 million metric tons of wheat are harvested annually from 232 million hectares. Maize is a year-round or seasonal staple for at least 500 million people throughout Latin America and in parts of Asia and Africa, and increasingly important as a feed for cattle, swine, and poultry.

In the early 1960's, before CIMMYT became an international institution, the center's scientists and their Mexican colleagues won the world's admiration for the dramatic success of the first high-yielding dwarf wheats. Bred in Mexico, these broadly adapted varieties were transferred to spring wheat fields at varying latitudes and altitudes around the world, where they performed better than many local varieties under rain-fed conditions and spectacularly better under irrigation. By 1977, Mexican dwarf wheats from CIMMYT were planted on 30 million hectares—almost half the wheatland in the developing countries. Wheat production in India tripled from 1966 to 1979.

CIMMYT's strategy

CIMMYT's parallel Wheat and Maize Programs take several simultaneous approaches to the goal of increasing food production in the developing countries. Genetic improvement of maize and wheat cultivars is fundamental. Plant breeders carry out continuous programs to produce new genotypes with the potential to respond to improved farmer management under the conditions and constraints typical of the developing countries. At each stage of development, promising types are tested and selected on the basis of local adaptation by collaborating scientists in developing countries. The best performing of these lines are eventually named and released by national programs for local farmers.

Along with improved cultivars, CIMMYT develops research procedures to orient crop production programs. These procedures are designed to identify production constraints and to develop farmer recommendations to realize the yield potential of genetically improved plants under improved management. Like new seeds, improved farming methods are developed in close collaboration with developing-country scientists and tested and adapted by national programs.

Social scientists in CIMMYT's Economics Program work closely with the biological scientists to develop research procedures to identify social, cultural, and
economic factors that condition farmers' acceptance of improved seeds and production practices.

CIMMYT strengthens national agricultural research and production programs in developing countries in a number of significant ways. Collaboration with developing-country scientists and government programs is an inherent and vital aspect of CIMMYT's regional programs in wheat, maize, and economics. In addition, CIMMYT scientists and technicians work directly in many national programs, through frequent visits or long-term assignments. In turn, young agricultural graduates, degree candidates, and visiting scientists from developing countries come to Mexico for periods ranging from a few days to a year or more to improve their abilities to increase crop production.

MAIZE PROGRAM

Maize has the genetic potential for higher yields and broader adaptation to diverse agroclimatic conditions. Efforts to breed better maize plants, however, face a daunting variety of obstacles. First, the world's maize crop includes thousands of diverse plant and grain types that have been selected by farmers over centuries to satisfy local preferences for grain size, color, and texture; cooking qualities; resistance to local environmental stresses, pests, and diseases; as well as yield. For all its diversity, the tropical maize plant tends to grow tall and leafy, squandering photosynthetic energy that might go instead to producing grain. The tropical plant's need for plenty of elbow room, and its tendency to topple in high winds and heavy rains, depress yields. In many areas, tropical maize is vulnerable to attack by a variety of insects and diseases. Finally, the value of maize as a human food is limited by the deficiency of its protein in two essential amino acids, lysine and tryptophan.

Drawing on the world's most complete collection of maize germplasm, CIMMYT breeders are developing improved genotypes that will produce high yields under varying agroclimatic conditions. This is a departure from traditional efforts to increase maize yields by tailoring improved types for each different regime. CIMMYT's improved maize are open-pollinated types that can be grown by farmers with seed saved from the previous harvest, rather than inbred hybrids that require elaborate annual seed production and distribution.

One striking result of CIMMYT's maize breeding program is a tropical maize plant that is half the height of indigenous types, less leafy, and similar to temperate-zone maize in grain productivity. The improved plant can be densely planted, and it stands up well to tropical storms.
In collaboration with national programs in areas hard hit by maize diseases, CIMMYT scientists are working to increase the inherent resistance of tropical maize to three major diseases: downy mildew, streak virus, and corn stunt. Similarly, maize populations at CIMMYT are exposed to heavy attack by insect pests; only those plants that demonstrate good inherent resistance are selected for further improvement. Cultivars highly resistant to pests and diseases should permit farmers to obtain stable production less dependent upon the use of chemicals for crop protection.

The effort to improve the nutritional quality of maize uses a mutant gene called opaque-2, discovered at Purdue in 1963, that doubles the proportions of the essential amino acids lysine and tryptophan in maize protein, making its food value equal to milk's. Early opaque-2 maize, however, was characterized by soft, dull kernels that were unappealing to many consumers in the marketplace and vulnerable to insects during storage. These opaque-2 maize plants also yielded less in grain weight than normal plants. Intensive breeding and selection at CIMMYT, refined by trials in a number of countries, have produced opaque-2 types that combine quality protein with hard, shiny kernels that consumers find acceptable, with potential yields about equal to the best normal types.

For the future, radical new breeding methods offer the hope of making crosses with different genera, transferring their useful characteristics to maize. Tripsacum, a wild, grasslike plant, for example, is inherently resistant to many diseases and insects that attack maize. Sorghum outyields maize in waterlogged soil or drought conditions. CIMMYT carries on a modest program of research in "wide crosses" between genera, while encouraging and collaborating with scientists at other institutions.

WHEAT PROGRAM

CIMMYT wheat scientists carry on a very large breeding and selection effort to strengthen and extend the gains made by the high-yielding CIMMYT wheats during the past two decades. The rate of wheat improvement is doubled by growing two crop cycles per year in Mexico, one in the winter near sea level in the northwestern part of the country, the second in the summer on the central plateau at an elevation of 2,600 meters. In addition, by "shuttle breeding," alternate generations of promising wheat lines are grown in collaborating developing countries, where they are tested and selected under the agroclimatic conditions for which they are ultimately intended.

Improved disease resistance is a continuing concern of CIMMYT wheat breeders. Ironically, with the worldwide acceptance of the high-yielding Mexican wheats, vast areas are now planted with similar or identical genotypes, thus increasing the possibility of epidemic disease outbreaks. As a defense, CIMMYT breeders are developing multilines, which replace homogenous varieties with mixtures of different varieties that share one common parent and have similar plant heights, maturity periods, grain types, and yield potentials, but different genetic sources of disease resistance. CIMMYT distributes multiline components to interested developing countries, where appropriate mixtures can be made for local conditions.

Working to develop nutritionally improved maize, CIMMYT has succeeded in breeding high-yielding maize with the protein quality of milk.
In another effort to improve the disease resistance of bread wheats, as well as to increase their resistance to cold and drought, CIMMYT breeders are working closely with colleagues in developing countries to exchange useful genes between spring and winter types. So far, the best spring wheats with some winter wheat genes are yielding up to one ton more per hectare than the best normal spring wheats.

Durum wheat—used extensively in North Africa, the Middle East, India, and parts of South America for such products as pasta, unleavened bread, chapatis, bulgur—has been improved at CIMMYT until its yields equal or surpass the best bread wheats. Continued durum breeding in Mexico is aimed at increasing resistance to major diseases.

In certain adverse environments, even the best wheats are outperformed by triticale, the first man-made cereal, resulting from a wide cross between wheat and rye. Triticale’s protein quality is superior to bread wheat’s, and the flour is excellent for a variety of baked products. There is growing interest in triticale in Mexico, Brazil, East Africa, and the lower ranges of the Himalayas, particularly in areas where highly leached, acid soils give triticale a considerable production advantage over wheat.

Barley is another traditional alternative crop where other cereals are limited by drought, short growing seasons, and alkaline soil. CIMMYT has been working in close collaboration with ICARDA to combine genetic disease resistance in desirable plant types, and to develop barleys with stronger straw, better root systems, higher-quality protein, and early maturity to escape drought. Naked-grain types, lacking the hard hull that must be laboriously removed before normal barley can be eaten by humans, are being developed to make barley more attractive to consumers. Very early barley materials, which provide an added margin of drought escape, are also being developed for the more marginal barley-producing areas.

ECONOMICS PROGRAM

CIMMYT’s commitment to economic research has grown rapidly in recent years, as nonagricultural factors have been identified as major impediments to increased crop production in developing countries. CIMMYT economists work closely with biological scientists to identify and analyze public-policy issues such as the organization of agricultural research and extension; the distribution and pricing of seed, fertilizers, and chemicals; the availability of credit; the development of infrastructure; and market conditions. In on-farm research, CIMMYT economists have developed practical survey procedures to identify social and economic considerations that affect farmers’ acceptance of new technologies, in order to assist biological scientists to orient research designed to make relevant and practical production recommendations to farmers.
International Board for Plant Genetic Resources

The International Board for Plant Genetic Resources (IBPGR), headquartered at FAO in Rome, was established by the CGIAR in 1974. Its basic function is to promote an international network of genetic-resources centers to further the collection, conservation, documentation, and use of plant germplasm. The successful accomplishment of this task will prevent the threatened loss of significant genetic diversity of many crops in a time of great change and development in agriculture and land use, including the introduction of new varieties, and will provide genetic resources for future progress in plant improvement.

Of the several thousand plant species that man has used for food during his brief history as a cultivator, only a few hundred are cultivated today, and a mere handful of these make up most of the human diet. The accumulated genetic diversity of these cultivated food plants, their primitive landraces, and their closely related wild or weedy forms is the source from which all improvements in food crops are derived. The loss of these genes, or the failure to discover their existence, therefore, represents a potential opportunity lost.

The emerging IBPGR network includes centers concerned with specific crops or groups of crops, and centers concerned with all crops in a particular geographical area, national or regional. The IBPGR has accepted the responsibility assigned to it by the CGIAR to encourage and, where necessary, support an appropriate and coordinated global program of genetic-resources activities by these various centers, and to foster collaborative efforts among them.

A growing number of governments and international agencies are becoming actively interested in the systematic collection and conservation of the germplasm of at least the most important economic plant species. Indeed, the board has emphasized the remarkable catalytic effect that its establishment and operations have had upon the genetic-resources activities of many nations around the world and of many international, regional, and national agricultural research centers. The agricultural research community has responded promptly and effectively to the lead which the board has provided.

FUNCTIONS AND OBJECTIVES

Unlike the other centers in the CGIAR system, the IBPGR is not a research but a service organization. Its work falls into four principal categories: (1) activities designed to encourage and support collection, conservation, and other measures necessary to assure the availability for future breeding programs of the genetic diversity of specific crops of major economic importance (these activities are supported usually in response to global needs); (2) activities designed to assist in strengthening the genetic-resources programs of specific countries and regions, particularly centers of genetic diversity (such programs include collection, storage, characterization, and other activities); (3) information activities designed to assure that information concerning all major genetic-resources collections is documented, so that at least the minimum necessary data about the accessions in those collections can be readily available to potential users; and (4) training programs of various kinds designed to assure that trained personnel are available for the foregoing activities. The board's work in each of these categories consists primarily of providing encouragement and technical
and financial support for the work of other organizations, national, regional, and international, on plant genetic resources.

ACTIVITIES AND ACHIEVEMENTS

The IBPGR has organized, in cooperation with the relevant international centers within the CGIAR system, Crop Germplasm Advisory Committees for wheat, rice, maize, sorghum and millets, and *Phaseolus* beans, which serve in effect as a bridge between the board and the global community of scientists working on these crops. Each advisory committee has reviewed the current state of the germplasm collections and storage facilities of the particular crop in question, has indicated where additional collections need to be made and by what institutions they can best be made, has advised on where base collections should be maintained and on the adequacy of existing facilities for medium-term and long-term storage, and has recommended a minimum standardized list of descriptors for use in documenting collections of the crop. For potatoes, the Centro Internacional de la Papa provides similar advice to the board. And for crops of somewhat less global importance, *ad hoc* working groups have been created with terms of reference comparable to the advisory committees' but with a more limited life span. Such working groups have been organized for bananas and plantains, coconuts, tropical vegetables, beets, groundnuts, and coffee.

Plans of action recommended by these advisory committees and working groups have been approved by the board and have been or are being carried out worldwide. In addition, the board has arranged for an intensive series of collections in specific regions where the risk of genetic loss is especially high, particularly the Mediterranean region, Southwest Asia, and the Sahelian zone. The board is also encouraging and supporting the development of regional genetic-resources programs involving cooperation among a number of nations of a region, of which the most successful to date has been in Southeast Asia.
In consultation with the centers concerned, the board has designated a number of specific institutions as responsible for maintaining the world's major base collections of seeds of the principal food crops. These institutions form part of the board's global network in which over 60 national, regional, and international agricultural research institutions participate.

In order to assure that the germplasm that is collected is properly conserved, the board has developed and published recommended standards for the engineering and design aspects of long-term seed-storage facilities, and it is assisting a number of centers to improve their facilities to meet the recommended standards. It is also supporting research and training in seed-conservation technology.

Many existing germplasm collections are not adequately documented, yet no collection is worth more than the information available about the accessions that it contains. Accordingly, the board is assisting in the development and installation of appropriate documentation systems for several centers holding major genetic-resources collections that enable the curators of those collections to store and retrieve information about the characteristics of the seeds held in storage.

The IBPGR plans to add additional major food crops to its activities at the rate of three or four per year in the immediate future. At the same time, the board will pay increased attention to crops that are minor on a world scale, but of substantial local importance; and to fruit trees and vegetatively propagated species. Pilot work on certain aspects of forest germplasm conservation is also being undertaken.
The primary concern of the International Center for Agricultural Research in the Dry Areas (ICARDA) is rain-fed agriculture in a region that includes much of the vast arid and semi-arid areas of North Africa and West Asia. This region has a Mediterranean-type climate, with hot, dry summers and relatively cool, moist winters. Those parts of the region receiving ICARDA’s attention are limited in their opportunities for agricultural improvement by lack of water, having annual rainfall values ranging from 600 mm down to 200 mm or even less, making sustained agriculture difficult.

From Pakistan in the east to Morocco in the west, most of the countries in ICARDA’s region are struggling to feed themselves; in most years, they fall short of the goal. The region’s chronic food deficit is among the most serious in the world. With population growing rapidly and the cost of food imports rising along with general price inflation, the people of the area are usually eating less with each year.

In its effort to increase food production and raise rural living standards in the region, ICARDA maintains programs for the improvement of three principal groups of food crops: basic cereals, including bread wheat, durum wheat, barley, and triticale; legumes, including lentil, chickpea, and faba (or broad) bean; and forages. As an essential complement to the crop programs, the farming systems program develops improved techniques and technologies for exploiting the high-yield potential of improved crop varieties acceptable to traditional farmers.

ICARDA researchers are also studying the relationships between soils and crops and the potential for management of soil water and nutrients under the various climatic conditions in the region. The major emphases of this research are nitrogen and phosphorus fixation, nitrogen mineralization, and the subsequent use of nutrients by crops in various rotations under different conditions of soil fertility and moisture. Specific studies of traditional and potential cropping systems, including crop-livestock mixtures, are important for the integration of the center’s crop-improvement, agronomy, and livestock-management research. Studies on weed control will enable researchers and farmers to compare the relative benefits of the increased crop production resulting from eliminating weeds with the value of weeds as livestock feed.

CEREAL PROGRAM

Because of its superior efficiency in using available water, barley is grown throughout the ICARDA region in environments that are too risky for other crops. Some 10 million hectares in western Asia, the Middle East, and North Africa
are planted to barley, yielding about 10 million tons of grain. The generally low yields are the result of reliance on traditional local varieties, the lack of research and development on high-yielding varieties and farming systems, and the low market value of barley in comparison to wheat. ICARDA’s barley research emphasizes the development of improved varieties and production methods for low-rainfall areas, dual-purpose barleys suitable for both grain production and livestock grazing, and naked types for food and feed.

In many countries of the region, especially in the drier areas, where it outperforms bread wheat, durum is the dominant wheat type. Little research has been devoted to developing improved durums for the conditions in the ICARDA region; this is an excellent opportunity for the center to contribute significantly to increased food production in some of the poorest areas.

Bread wheat is the major crop of the region. Ninety percent of the crop is harvested from rain-fed land, half of which gets less than 400 mm of annual rainfall. The available high-yielding bread wheats, however, perform best in fertile soils under irrigation. ICARDA is developing high-yielding varieties adapted to rain-fed farming in low-rainfall areas.

For the areas with more moisture, ICARDA’s breeding program is incorporating genetic resistance to the diseases that inhibit cereal production in the region. The center also assists in the maintenance of a regional survey of wheat and barley rusts, providing national crop programs with advance warning of the evolution and spread of new forms of virulence.

The potential importance of triticale—a man-made wheat-rye cross—in the region’s future food production has become of increased interest at ICARDA since the recent improvements in triticale germplasm. The yield potential of the best triticale varieties under experimental conditions has been demonstrated. ICARDA’s scientists are investigating the new cereal’s adaptation to various environments in the region and its suitability for prevailing farming systems and consumer preferences.

For durum and bread wheat, as well as for triticale, ICARDA researchers are developing spring varieties and appropriate production methods to take advantage of winter moisture. Improved grain quality is also an important objective of all three cereal programs.

LEGUME PROGRAM

Among the food crops in ICARDA’s region, legumes are second in importance only to the cereals. ICARDA has worldwide responsibility in the CGIAR system for lentils and faba (or broad) bean; it has only regional responsibility for chickpea in collaboration with ICRISAT, the major center for chickpea research.

Faba (or broad) bean is the world’s fourth most important pulse. Two-thirds of the world’s production is in China; 14 percent is in ICARDA’s region, in North Africa and western Asia. ICARDA researchers have identified high-yielding lines for both dry-seed and green-vegetable production, incorporating good drought tolerance.

Farming systems research aims at understanding the farmer’s natural and social economic environment in order that new technologies can be applied with maximum benefit.
Farmers visit ICARDA trials to review research achievements.

and resistance to major diseases.

India is the leading producer of lentils, followed by Turkey, Ethiopia, and Syria. More than 40 percent of the world’s lentil production is in ICARDA’s region. The center’s scientists have conducted significant trials for yield, stability, adaptation, and drought tolerance. Many of the 4,000 genotypes in the center’s collection have been screened for suitability for mechanical harvesting, with promising results.

More than 80 percent of the world’s chickpea production is in eastern Asia and the Indian subcontinent; 9 percent is in ICARDA’s region. By agreement with ICRISAT, ICARDA has undertaken the development of the larger-seeded kabuli types throughout their range. From its collection of 3,300 chickpea genotypes, ICARDA researchers are selecting for resistance to Ascochyta, a blight that is especially severe in winter; cold tolerance; and generally higher yield. By adapting high-yielding chickpeas to winter conditions, the research will allow farmers to plant in the winter, affording the crop a longer growing period.

Agronomic research in the legume program has identified optimum levels of important factors such as seeding rate and date, moisture level, and fertilizers. Several promising strains of Rhizobia have been identified for all three legumes and are undergoing further research.

FORAGE PROGRAM

From 15 to 50 percent of the total agricultural production in the countries of the Middle East and North Africa is in the form of livestock, especially ruminants. In many countries, animal husbandry is more than one economic activity among others; it is an important element in the culture. In recent years, however, livestock production in the region has lagged behind population growth. Among the prime causes of declining per capita production are the widespread deterioration and desertification of rangeland and the displacement of forages by cereals.

The potential for increasing forage production in the region is great: much of the 35 to 40 million hectares of rain-fed cropland fallowed each year could be used instead to grow forages. Little work has been done on the selection and breeding of improved forage crops for western Asia and North Africa. ICARDA is especially interested in the annual and perennial medics, vetches, forage cereals and grasses, and rangeland grasses and shrubs.

For future breeding, the center is collecting, analyzing, and maintaining germplasm of promising species. Potential breeding stock is being selected for yield, persistence, and cold tolerance. Forage-crop management systems are being developed for a variety of environmental conditions and farming systems. Basic ecological studies of rangelands are laying the groundwork for better use of existing forages, the reintroduction of valuable species that have been eliminated by mismanagement, and the introduction of superior exotic species.
The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), established in 1972, was the first of the international centers to be created under the aegis of the Consultative Group on International Agricultural Research. The semi-arid tropics include large parts of Africa, Asia, Latin America, India, and the Middle East, with a combined population of some 600 million, most of whom subsist by dryland farming.

The dryland farmer of these regions faces daunting obstacles: his soils are often virtually exhausted and deeply eroded. He has little or no access to fertilizers, technology, or capital. The only power sources he has, human and animal, are debilitated by chronic malnourishment. His crops are unprotected against pests and diseases. Withal, his most serious problem is water, which typically comes in brief, irregular, and destructive storms during the short rainy season; and then comes not at all during the long drought. Under these disheartening circumstances, the resource-poor farmer of the semi-arid tropics relies prudently on traditional crop varieties that, although not high-yielding, have been developed over the years to withstand the severe stresses of this harsh environment.

ICRISAT's purpose is to improve substantially the quantity and reliability of food production in the semi-arid tropics by improving both the cultivated varieties (cultivars) of major food crops and the management of soils and water. The institute's efforts are focused on the conditions of the poor farmer, with little land or other resources, who makes up most of the population and produces most of the food in the region.

ICRISAT concentrates on five major rain-fed food crops grown by resource-poor farmers: among the cereals, sorghum and pearl millet; two pulses or grain legumes, chickpea and pigeonpea; and groundnut, or peanut, which is also a legume. In addition to its work on improved cultivars and farming systems, the institute maintains an economics program to investigate the social and economic factors that condition farmers' responses to improved technologies and define their needs; and extensive programs of training, cooperative research, and international information-sharing.

SORGHUM PROGRAM

Sorghum, grown on 43 million hectares in both tropical and temperate zones, is a major food crop in India and in much of Africa, where—with pearl millet—it is the major source of food calories. Although sorghum originated in the semi-arid tropics ICRISAT emphasizes animal power and simple implements in its farming systems program. ICRISAT Center in background.
of Ethiopia and the Sudan, sorghum yields in the tropics today are only one-fifth those in the developed countries, where sorghum is fed to livestock.

Attempts to develop higher-yielding sorghums for the semi-arid tropics are complicated by the extreme variations in plant types preferred by farmers, and in the grain sizes, colors, and textures favored by consumers. In selecting and breeding for different agroclimatic conditions and local requirements, ICRISAT scientists draw on a world germplasm collection that currently numbers more than 19,000 accessions.

High on the list of desirable characteristics is resistance to pests (shoot fly, stem borers, head bugs, and midges), diseases (grain molds, downy mildew, charcoal rot, and leaf diseases), witchweed, and drought. Sorghum scientists are also developing methods and selecting materials for improved plant types; response to day length; grain-yield stability and quality; improved tolerance to water, heat, cold, and nutrient stresses; and better crop establishment.

PEARL MILLET PROGRAM

One of a large group of millets, pearl millet is grown on approximately 25 million hectares in the semi-arid tropics, especially in southern Asia and Africa, where it is a staple food. It is notable for producing grain under even the worst conditions; it is superior to sorghum in tolerance for drought and low soil fertility. Pearl millet also has the ability to tiller profusely and repeatedly, so that the first and second growth can be cut for forage and the third shoots will still produce mature grain. Protein levels in pearl millet normally range between 8 and 12 percent, but lines up to 20 percent protein have been identified. Yields in the semi-arid tropics average between 400 and 600 kilograms per hectare, but yields of more than 3,000 kilograms per hectare have been achieved at ICRISAT, and even higher yields are anticipated.

ICRISAT’s pearl millet germplasm collection numbers over 12,000 entries, including a wide selection from India and Africa. ICRISAT’s breeders are seeking genes for higher yields, tolerance to environmental stresses, pest and disease resistance, protein quality, and attractive grain quality. Resistance to downy mildew and ergot is especially important, because these two diseases have presented the greatest threat to the adoption of high-yielding hybrids in India. Significant progress has been made in identification and utilization of resistance to these diseases.

The breeding program is currently working with synthetic varieties developed by several generations of selection from composite populations and with F1 hybrids and composite varieties. Several major composite populations—including early-, medium-, and late-maturing, and dwarf—are under rapid improvement using recurrent selection breeding techniques.

PIGEONPEA PROGRAM

The pigeonpea is grown on nearly 3 million hectares worldwide, about 90 percent of them in India, where the pulse is often interplanted with sorghum or millet. The green peas and pods, as well as the dry peas, are edible, and the woody stems are used as fuel. The plant’s deep root system enables it to withstand drought. Current world yields of pigeonpea average about 600 kilograms per hectare, but more than 3,000 kilograms per hectare have been achieved with some Indian cultivars under experimental conditions; even higher yields are expected from further-improved genotypes.

The recent development of dwarf plant types suggests the possibility of higher planting densities and grain-to-foliage ratios. Cultivars with 15 to 28 percent total protein have been identified. ICRISAT scientists have identified several sources of genetic resistance to important diseases and are in the process of identifying sources resistant to pests, especially the pod-boring insects. Several wild species hold promise in this respect. The recent discovery of male-sterile types of pigeonpea holds out the hope of producing high-yielding hybrids.
Good progress has been made in identifying early maturity lines with high yield. These are more suited for rotation with wheat in northern India. In cooperation with the University of Queensland, Australia, short-duration photoinsensitive lines have been identified. These will enable farmers to grow more than one crop per year.

Pigeonpea breeding at ICRISAT is based on a collection of more than 8,800 accessions.

CHICKPEA PROGRAM

Chickpea is the world’s third-ranking pulse crop and the leading pulse of Ethiopia, Pakistan, Turkey, and India. Three-quarters of the 10.5 million hectares planted to chickpea are in India; the rest are in 32 other countries of Asia, Africa, and Latin America. Both the dry and green peas are eaten. The protein content of the chickpea ranges from 17 to 30 percent, although, as in most pulses, the protein is low in sulfur amino acids, especially methionine.

Current yields in India average about 700 kilograms per hectare, but 3,000 kilograms per hectare have been achieved under experimental conditions. In India, the crop is grown on residual moisture in the dry winter season, after the rainy-season crop has been harvested. Most varieties used in the developing countries have low resistance to wilt, root rots, and Ascochyta blight, and relatively inferior genetic potential.

ICRISAT breeders are working to develop superior chickpeas by exchanging genes between the large-seeded kabuli types, which are grown in the spring and summer in western Asia, North Africa, and the Middle East, and small-seeded desi types, grown during winter in South Asia. The objectives of the breeding program are higher and more stable yield, improved consumer acceptability, resistance to diseases and pests, and improved protein quantity and quality. The mystery of the so-called wilt complex has been solved, and the major disease components of the complex have been identified as wilt, dry root rot, and stunt (virus). Sources of resistance to these three diseases as well as to Ascochyta blight have been identified.

The Genetic Resources Unit has assembled, studied, and catalogued thousands of chickpea genotypes, some of which were collected on expeditions to remote areas of semi-arid Asia. The germplasm collection now totals over 12,000 accessions. ICRISAT’s breeding program, in collaboration with ICARDA, maintains chickpea nurseries in various agroclimatic zones, including the Middle East and in the foothills of the Himalayas. The institute is involved in cooperative programs with chickpea scientists in central and northern India, and conducts international trials in Asia, the Middle East, Africa, and Latin America.

GROUNDNUT PROGRAM

Groundnut, or peanut, was added to ICRISAT’s agenda after a study by world experts and CGIAR review, and the research program actively commenced in 1976. With 25 percent protein and approximately 50 percent oil, groundnut is an important food crop in many areas of the semi-arid tropics and the world’s most important source of edible oil after soybean and cottonseed. Although groundnut is an important cash crop as well as food crop, yields
in the semi-arid tropics are stagnant at about 800 kilograms per hectare, compared with more than 2,000 kilograms per hectare in developed regions.

The main objectives of the breeding program are to produce high-yielding materials with stable resistance to diseases, pests, and drought. The main fungal diseases are the leaf spots, rust, pod, seed, and seedling disorders, including fungi that produce mycotoxins. New sources of rust resistance have been found in the cultivated groundnut collection, and some of these cultivars have tolerance to leaf spots as well. Wild species highly resistant or immune to the two leaf spot fungi are being utilized as parents in interspecific breeding programs with cultivated groundnuts. Important viral diseases of groundnuts are being studied and sources of resistance are being sought. The viruses causing these diseases are being isolated and precisely characterized. Breeding lines with high yield, earliness, and disease resistance are currently being distributed to researchers in other countries.

The germplasm is also being screened for resistance to the major insect pests, and integrated pest control programs are being formulated. The groundnut germplasm collection now holds more than 8,300 accessions.

Groundnuts can be very efficient fixers of atmospheric nitrogen. Attempts are being made to manipulate the Rhizobium and host plant component of the symbiosis to increase nitrogen fixation and yields, as well as increasing the residual fixed nitrogen that can benefit subsequent crops in the rotation.

FARMING SYSTEMS PROGRAM

Improved farming systems are essential to making maximum use of improved cultivars in the effort to increase food production. Traditional farming systems throughout the vast semi-arid tropical areas of three continents, however, are so diverse as to defy generalization. The prime common factor that must be taken into account in any viable farming system is the inadequacy and irregularity of the water supply. Long, deadly droughts are interspersed with storms of excessive rain that ruin crops, erode soils, and leach nutrients.

ICRISAT's farming systems researchers are developing systems to moderate the extremes in water supply and reduce erosion and nutrient loss. Other studies center on improved animal-drawn equipment, weed control, mulching, use of fertilizer, efficiencies of various mixed cropping systems, and utilization of weather data. This research is now being evaluated in on-farm experiments conducted in cooperation with national scientists, agricultural universities, and farmers in selected villages of India.

One of the most dramatic developments in ICRISAT's farming systems research has been demonstration, within the research station, that two crops a year can be grown on the types of deep black soils that in much of India are now used only for a post-rainy-season crop because they are too wet and sticky to cultivate in the rainy season through traditional methods. The improved technology involves: prediction of areas where rainfall is sufficient to assure reliable double cropping; shaping the land into graded broadbeds and furrows to facilitate cultivation and surface drainage; preparing seedbeds
during the dry season; sowing dry ahead of the rains; using improved cultivars and combinations of crops; applying improved fertilizers.

Having demonstrated the benefits and reliability of this technology for double cropping within ICRISAT Center over the past eight years, the institute is now prepared to test it on a broader scale in black soil areas of India having assured rainfall.

Farming systems experiments are also being intensified in Africa as part of ICRISAT's global research effort.

**ECONOMICS PROGRAM**

The function of ICRISAT's economic research is to fit new technologies and crop genotypes to the actual needs and the social and economic conditions of farmers. To gain an intimate understanding of traditional agriculture in its matrix of cultural attitudes, economic constraints, and living patterns, ICRISAT researchers have gathered several years' data from long-term village-level studies. Such socioeconomic research yields valuable insights into the many subtle factors that determine farmers' needs and their attitudes toward innovation and risk. These village-level studies formed the basis for on-farm experiments now being conducted by ICRISAT in collaboration with national scientists and village farmers. Similar studies, and market research such as that done in India, are now being undertaken by ICRISAT economists in West Africa.
The International Food Policy Research Institute (IFPRI), alone among the centers in the CGIAR system, is concerned with the issues arising from the intervention of governments and international agencies in national, regional, and global food problems. In association with policymakers, administrators, and others responsible for increasing food production and with improving the equity of food distribution, IFPRI identifies important food-policy issues; collects, organizes, and analyzes information relevant to social, economic, and agricultural research; and defines and analyzes alternative responses.

The institute was established in 1975 following the recommendation of the CGIAR and its Technical Advisory Committee, USAID, and a number of agencies and institutions from developing countries. Under the initial sponsorship of three nongovernmental members of the CGIAR—the International Development Research Center of Canada and the Rockefeller and Ford foundations—IFPRI was designed as an independent, autonomous research organization that would work objectively and credibly on important issues of the most profound political and social significance.

The institute's research focuses on three prime factors in the food situation: food production, especially as it is affected by technological change; food distribution and consumption, with particular attention to effects on poor people; and international food trade. A fourth IFPRI program, on trends and statistics, compiles and analyzes data on past food production and consumption in the developing countries and extrapolates future trends.

**FOOD-PRODUCTION PROGRAM**

The program's major interests are production strategies; production and investment policies; and the relationships among various factors in economic growth, especially growth led by rural development. In its work on production strategies, IFPRI is analyzing the experiences of various developing countries in order to identify conflicts between agricultural development and equity; to describe policies that can mitigate such conflicts; and to examine the effects of development, especially development based on new technology, on agricultural production.

In consultation with other international centers and national programs, IFPRI is undertaking a study of farming systems in the Sahelian region of West Africa. The study will discuss factors that inhibit adoption of proposed innovations; assess the microeconomic implications of acceptance of new technology; and define the complementary or competitive roles of food crops, export crops, and livestock in the regional economy.

In the area of production and investment policies, a 1979 IFPRI study assesses the capital investment and agricultural inputs needed by 36 present or potential food-deficient countries if they are to avoid serious food shortages by 1990. A sequel to this study examines the factors affecting the growth of fertilizer use in developing countries.

**FOOD-DISTRIBUTION AND CONSUMPTION PROGRAM**

The program's research and analyses focus on food-distribution policies, consumption patterns, and effects of food-price policies and technological change on
income distribution, food consumption, and nutrition. A major case study in three Asian countries examines the effectiveness of comprehensive public food-distribution schemes, which represent the most significant attempts to increase food consumption by direct government initiatives. Another study examines a recent decline in per capita grain consumption in India, despite an increase in per capita income. A study of Brazil's ambitious price policy measures its effects on crop production, prices and price stability, farm income, and the distribution of benefits between farmers and nonfarmers.

FOOD-TRADE PROGRAM

The program examines international food-trade issues and domestic-trade policy in developing countries. The international food-trade issues of particular interest to IFPRI include the problem of food security for food-deficient developing countries, the potential of agricultural exports as a major source of foreign exchange to finance food imports, and food aid. In its research on food security, the subject of a major 1979 study, the institute attempts to assess the nature and magnitude of food security in specific countries in Asia, Africa, the Middle East, and Latin America, and to examine the relative merits of alternative solutions involving both national and international initiatives.

As part of the work on food security, a major wheat study analyzes the world wheat economy, the system of wheat reserves, and proposals for a new (international) Wheat Trade Convention. A study on food-aid requirements of the poorest countries projects the magnitude of the need and estimates the portions unlikely to be met by commercial imports, and thus to be covered by food aid. Research on agricultural exports includes a study of the potential benefits to the developing coun-
In its research on food security, IFPRI has concluded that any international food security scheme must be assessed in conjunction with the specific programs in the recipient countries for assuring that the food reaches the lower-income people.

Tries of trade liberalization, the distribution of those benefits among countries, and the commodities with export potential in each region.

The effects of domestic-trade policies on the food security of developing countries is the subject of IFPRI research in Southeast Asia and the Sahel. In the rice economies of Southeast Asia, the institute is measuring the effectiveness of short-run supply management in assuring stable rice consumption. In the Sahel, IFPRI is evaluating the costs and benefits of various trade, storage, and insurance policies designed to stabilize food consumption in the region.

A special study focuses on Colombia's general trade and exchange rate policies and their effects on food and agriculture production, consumption, foreign exchange earnings, and income distribution.

FOOD TRENDS AND STATISTICS PROGRAM

From past and projected trends in food production, consumption, and deficiencies in developing countries, the program attempts to predict where future food problems are likely to occur, their magnitude, and their general implications for food policies in these countries. The program's major project is a periodic assessment of the global food situation, using current and historical data to project the food requirements of the developing countries to the year 2000. Originally limited to developing countries with market economies, the program's coverage of countries has been broadened to include the People's Republic of China and other centrally planned Asian economies. Its commodity coverage will increase beyond the original focus on major staples to include livestock and dairy products.
IITA
International Institute of Tropical Agriculture

The International Institute of Tropical Agriculture (IITA) was the first agricultural research center on the African continent, and its construction was started in 1967 in Ibadan, Nigeria. Its scope is worldwide. Originally concentrated on the lowland tropics of Africa, its research has expanded to other continents and to some subhumid and even semi-arid environments. In the CGIAR system, IITA has worldwide responsibility for the improvement of cowpea, yam, cocoyam, and sweet potato; and regional responsibility for cassava, rice, maize, soybean, lima bean, winged bean, and pigeonpea. IITA's concentration on basic food crop improvement programs—Roots and Tubers, Cereals, and Grain Legumes—is a radical departure from earlier crop research in the tropics, which concentrated on valuable export crops.

Another major program at IITA is devoted to improving traditional farming systems. The objective of the farming systems program is the development of more productive and ecologically sound alternatives to traditional systems of bush fallow and shifting cultivation. Under the traditional systems, a brief period of cropping—two to three seasons, with declining returns—is followed by a much longer period of fallow, during which natural vegetation restores nutrients and organic matter to the soil. Under the pressure of increasing populations, however, the growing demand for agricultural production has led to shorter periods—or no fallow periods at all—between cropping seasons. The general consequences are often irremovable deterioration of the soils’ physical structure, increased erosion, total loss of soil fertility, and problems with weeds, insects, and diseases. The net result is a sharply declining production per unit of land. Present research work on different systems of land clearing, crop rotation, and crop protection shows very promising results for an early solution to this fundamental problem in the humid tropics.

Unlike the Nigerian local cassava varieties (background), IITA has developed higher-yielding, early-maturing, and disease-resistant cassava lines (foreground), which are being used in many cassava-growing areas. The improved lines yield about three times the local yield.
Sweet potato weevil is a destructive pest, damaging the tuber before and after harvest (right). IITA root and tuber scientists have now developed varieties of sweet potatoes resistant to the weevil (left).

ROOT AND TUBER PROGRAM

Cassava is the major source of calories for more than 300 million people in the tropics. IITA scientists have identified sources of genetic resistance to cassava mosaic disease and cassava bacterial blight, major diseases of the crop. This resistance has been incorporated into high-yielding cultivars. Improved disease-resistant cassava clones, distributed to farmers in Nigeria, are yielding about 30 tons per hectare, compared with yields of 10 tons from traditional varieties.

Two major insect problems of cassava —mealybug and green spider mite—receive a major emphasis. Prospects for genetic resistance to green spider mite and biological control of mealybug seem to be good.

Using recently developed techniques for propagating yam from seed, IITA researchers have grown more than 100,000 genotypes with a great diversity of plant and tuber types, flowering and fruiting habits, and insect and disease resistances. These materials are being used by breeders at the institute and in national programs around the world to produce improved varieties.

Sweet potato lines bred at IITA exhibit conspicuous resistances to virus and weevil. Yields of these insect-and disease-resistant materials average 20 to 30 tons per hectare without fertilizers, compared with farmers’ yields of about eight tons with traditional varieties.

Cocomams are grown throughout West Africa and are especially important in Cameroon and Ghana. Erratic flowering of the plant under natural conditions has impeded efforts to breed improved varieties. Using new techniques to induce flowering, IITA researchers have grown 1,000 seedlings for selection and further crossing to produce improved cultivars.

CEREAL PROGRAM

IITA cooperates with CIMMYT in maize research and with IRRI in rice research.

Early-maturing maize is needed in many African countries where two plantings per season are possible. IITA has developed a variety, designated TZE, that matures approximately three weeks earlier than other maize; further improvement of yield is in progress. Another IITA maize, TZSR, is resistant to maize streak virus. Other maize lines are being converted to streak resistance in cooperation with national maize programs.

IITA’s rice researchers are seeking high-yielding varieties with drought tolerance and resistance to blast. Horizontal resistance to blast disease has been identified in some upland varieties in tropical Africa. These varieties are being crossed with improved semi-dwarfs to combine resistance with high yield. At the same time, semi-dwarf mutants are being sought in the upland varieties.

GRAIN LEGUME PROGRAM

Legumes are a vital source of protein for millions of people in the tropics. Because they associate with Rhizobia that can fix atmospheric nitrogen, enriching the soil and eliminating the need for costly commercial nitrogen, they are also an important component of mixed-cropping systems and the farming systems research program. IITA’s legume research concentrates on cowpea and soybean.

On a network of experimental sites extending from the dry savannah in Niger to the humid forest of Nigeria, IITA is selecting cowpea genotypes for breeding to develop improved cultivars. The cowpea is
vulnerable to a variety of insect pests; inherent pest resistance is being sought to decrease the farmers' reliance on expensive chemical insecticides. Eight high-yielding lines have already been released to national programs for use as new varieties or as breeding materials.

Soybean is a potentially important commercial crop in Africa, as demand increases for edible oil and high-protein food for humans and animals. IITA researchers have identified soybean varieties from Southeast Asia that associate with a wide variety of *Rhizobia*, including many that are indigenous to African soils. High-yielding soybean lines with seed that resists deterioration in the hot, humid climate of the lowland tropics are being developed.

**FARMING SYSTEMS PROGRAM**

IITA's farming systems research is directed at developing improved methods of efficient, sustained crop production that are compatible with the technical, economic, and social circumstances of subsistence farmers in the tropics. Improved farming systems are designed to take maximum advantage of IITA's improved crop varieties. Both improved varieties and improved cropping systems are brought to the attention of national programs for further adaptation to local conditions. The program includes activities in soils and environments, crop protection and management, small-farm machinery, postharvest technology, and agricultural economics.

In IITA's research on farming systems, zero tillage has proved advantageous and practical for the conditions common to many tropical countries. IITA's agricultural engineers have designed farm tools suitable for subsistence farming. The engineers are encouraging local blacksmiths to manufacture these tools to make them easily available to farmers and to promote local small industry. Intercropping, a traditional feature of African agriculture, is the subject of detailed research. In collaboration with FAO, a rural storage project has improved the design of cribs for maize storage on small farms and is exploring other grain storage alternatives.
The International Laboratory for Research on Animal Diseases (ILRAD) was established in 1974 to assist in the development of effective controls for two major livestock diseases: trypanosomiasis and theileriosis. Together, these two diseases prevent livestock production in vast areas of some 50 developing countries in Africa, Central and South America, the Middle East, the Indian subcontinent, and Asia. The total loss in human and economic values—not only in milk and meat, but also in leather, wool, fertilizer, animal power, and other animal by-products, and in potential capital resources—is incalculable. Hundreds of millions of people, among them some of the world’s poorest, are seriously affected. Ruminant livestock produce these materials from vegetation that man cannot eat, often on land that man cannot use for crops. In other areas, integrated livestock and cereal production are desirable.

ILRAD’s Strategy

Both diseases are caused by parasites that are transmitted by insect vectors; the tsetse fly carries trypanosomes while ticks transmit theileriosis. In both cases, the relationships among parasites, hosts, and vectors are subtle and complex; intervention is difficult. Also, in both cases, wildlife and domestic animals serve as alternate hosts for the parasites, creating reservoirs of infection virtually inaccessible to control measures.

Even if technically possible, the control of disease vectors requires systematic, timely, and costly measures that are clearly beyond the capabilities of the individual small farmer in the developing world. The emphasis of ILRAD’s research, therefore, is on the identification and exploitation of disease-control methods that rely on the immunological responses of the host animals.

While it supports a full and innovative program of original research, ILRAD also serves as a clearinghouse to integrate the various efforts of other national and international institutions that are working on the same problems from different perspectives. Through its collaboration with other institutions, ILRAD connects widely separated researchers with disparate specialties in a coordinated effort. At the same time, contact with far-flung institutions and programs enables ILRAD to design research programs that are relevant to actual conditions in the developing countries throughout the worldwide range of the target diseases.

Finally, ILRAD is a unique training center for the development of skilled professionals from national institutions and disease-control programs throughout the world. The center also provides a well-equipped facility and essential support to specialists from both developed and developing countries who are pursuing significant research in this crucial field.

In the first years since its inception, ILRAD has completed a thorough analysis of the scientific aspects of trypanosomiasis and theileriosis, including a survey of research completed and in progress throughout the world. An international research staff of scientists from 20 countries has been recruited. Research laboratories, facilities for animal production and maintenance, and support facilities are complete or in progress. A farm large enough to maintain a breeding herd of
1,600 cattle has been acquired to assure ILRAD researchers an adequate supply of disease-free experimental animals.

TRYPANOSOMIASIS PROGRAM

Trypanosomiasis occurs in man and in a number of domestic animals, including cattle, swine, sheep, goats, horses, and camels. The disease is caused by several blood parasites of the genus *Trypanosoma*. It is normally transmitted in cyclic manner by tsetse flies, but it can also be transmitted by biting flies, as in South Africa. In Africa alone, the disease depresses or prohibits livestock production in an area larger than the continental United States—an area that has the highest rainfall and the greatest potential for forage production of any in Africa.

Trypanosomiasis was the subject of ILRAD's initial search for immunity to disease in livestock. Because little is known about bovine immunological systems, the first step in the research was an analysis of cattle lymphocytes and immunoglobulins, which participate in immune reactions. Preliminary work on the disease organism itself included the analysis of the various forms of African trypanosomes in the tsetse vector and in the mammalian host; the various antigens produced by the parasite under different conditions; and the antibodies produced by the bovine host in response to the antigens. ILRAD researchers also are examining the inherited differences in the susceptibility of animals to trypanosomiasis in an effort to elucidate the basic mechanisms of resistance.

An important advance achieved at ILRAD is the first successful culturing of an African trypanosome. Established from a single organism, the cultures can be maintained through the parasites' life cycle indefinitely. The culturing technique is important in the analysis of the trypanosome's ability to change the chemical composition of its surface coat into 100 or more variants, frustrating the host animal's immunological system.

Other significant research at ILRAD has established that the antigens in the trypanosome's various surface coats, thought to be distinct, actually have common carbohydrate components. A possible implication of this discovery is that immunity to these carbohydrates might protect cattle against many forms of the parasite.

The trypanosomiasis infection also appears to have the ability to suppress immunological responses by the host. This phenomenon has been studied in detail at ILRAD, using laboratory mice. Similar studies on cattle are in progress. Meanwhile, work continues at the center on the disease vector, using tsetse flies produced in quantity by a special facility at the laboratory.

THEILERIOSIS PROGRAM

Theileriosis, or East Coast fever, is the most important tick-borne disease of cattle in East and Central Africa, killing an estimated several million animals annually. The disease is also a major problem in the Middle East, the Indian subcontinent, and East Asia. Where the disease is endemic, animals must be dipped, or otherwise
Various aspects of ILRAD's research: ILRAD scientists with fly trap; electron microscope; and checking infected animal.

treated against ticks, two or three times a week in infested areas. Such intensive treatment requires costly chemicals and facilities, as well as labor. Cattle must be driven long distances for treatment at frequent intervals, resulting in loss of weight, health problems, and damage to the land.

In the search for immunological control, ILRAD researchers are focusing on the decisive early events in theileriosis infection. In this research, *Theileria parva* sporozoites, produced in quantity by ILRAD's tick unit, are used to infect bovine cell cultures. The infected cell lines are then cloned to produce quantities of genetically uniform parasites. Experiments with these materials suggest that infection can be suppressed by cellular immune responses to parasitized cells. ILRAD scientists believe that immunization of cattle against theileriosis by vaccination is a real possibility.

If the possibility becomes a reality, all the techniques necessary for a systematic immunization program are fully developed at ILRAD: propagation, cloning, and storage of *Theileria* strains; production of animals free of *Theileria* and other parasites; and laboratory tests to verify immunological responses.

An experimental program to immunize cattle against theileriosis will require partially attenuated strains of parasites, strong enough to provoke the desired reaction but not strong enough to cause disease. Further trials will be necessary to determine the breadth of the protection conferred by the vaccination against the various strains of the parasite. Vaccine trials will begin in isolation units at ILRAD before moving to paddock conditions and finally into the field. These trials will be conducted in collaboration with the Kenya Veterinary Research Laboratories.
ILCA
International Livestock Centre for Africa

The International Livestock Centre for Africa (ILCA) was established in 1974 to assist national efforts in tropical Africa by carrying out research and development on improved livestock production and marketing systems; by training livestock specialists in the region; and by gathering documentation useful to the African livestock industry. ILCA is one of two centers in the CGIAR system to be devoted to livestock problems. Headquartered near Addis Ababa, Ethiopia, it is closely affiliated with the other livestock center, the International Laboratory for Research on Animal Diseases (ILRAD), in Kenya.

Tropical Africa, including Ethiopia, Mali, Nigeria, Kenya, and Botswana, has a human population of 300 million. It also has a population of 300 million ruminant livestock—mostly cattle, sheep, and goats. The unique economic value of these ruminants is their ability to make productive use of soils and vegetation that would otherwise yield nothing of importance for mankind. In addition to meat and milk, ruminants in tropical Africa provide hides and hair, traction and transportation, fertilizer and fuel. They also serve as vehicles for investment, savings, and capital formation. In traditional pastoral societies in Africa, livestock also figure importantly in social relationships and rituals.

The great majority of the people of tropical Africa depend on agriculture, and livestock and livestock products are a principal means of subsistence. The total value of annual livestock production in the region is approximately U.S.$2 billion. The productivity of livestock is low, however, while the human population of the region is growing at an annual rate of 2.6 percent. According to informed estimates, livestock production could be increased at least fivefold by adapting known technologies and animal farming systems to the special needs and conditions of tropical Africa.

Unlike most of the other, crop-oriented centers in the CGIAR system, ILCA is dedicated primarily to the development of improved varieties and associated technologies. Dealing with livestock rather than plants, in the context of deeply traditional, complex, and diverse farming systems, ILCA is more concerned with systems analysis and management approaches and techniques than with commodities. The center's role is to encourage the adaptation and application of superior technologies to the particular problems of livestock development in its region, introducing useful and appropriate innovations into traditional social, economic, and ecological systems.

ILCA's initial research effort has been the analysis of three major livestock production systems, adapted to tropical Africa's distinct arid, humid, and highland zones. A detailed understanding of these systems will enable the center to identify aspects that are susceptible to improvement and to design appropriate research and development programs.

The desirability of conducting parallel research efforts under different agro-climatic, social, and economic conditions has encouraged ILCA to decentralize. The regional subprograms are centered in Ethiopia, Mali, and Nigeria; parts of the program are further decentralized in Kenya and Botswana. These activities involve the center in frequent, close relations with the governments and national programs of many countries in the region. Some specialized research and much of ILCA's in-
formal and training activities are located at headquarters, but it is ILCA's field studies that are emphasized here.

ARID ZONES

With a mean annual rainfall of 300-600 mm, the arid-zones study area in Mali is mainly dry rangeland, but it also includes both rain-fed and irrigated croplands and seasonally inundated grasslands. Livestock are raised in traditional sedentary, nomadic, and transhumant—seasonally migratory—systems based mainly on cattle, but including also substantial flocks of sheep and goats. The variety of livestock and production systems in the area makes it especially fruitful for research.

ILCA's work in Mali has four principal components:

1. Studies of traditional livestock systems, especially the territorial and social organization of the transhumant system as it affects animal and resource management.
2. Testing of forage innovations in rain-fed millet cultivation and on irrigated rice lands. The purpose of these studies is to determine farmer response and effects on animal performance of simple innovations in each of these systems.
3. Formal experiments with innovations appropriate to these production systems and to their social and economic context.
4. Modeling of traditional production systems and innovations, to permit the correlation of research data, to assist in the choice of research priorities, and to allow the extrapolation of research results.

ILCA is also working in pastoral development schemes in other parts of tropical Africa, to assist national authorities in monitoring progress, and to understand better the dynamics of production under conditions of induced change.

HUMID ZONES

ILCA is studying two situations in Nigeria. In the forested belt—representing a subregion with some 30 million sheep and goats—the program is testing innovations to improve the production of these
small ruminants on smallholders' farms, in both existing village systems and more intensive management systems.

In the subhumid area, initial studies have identified the factors favoring and inhibiting traditional livestock systems. In the past, these areas have been grazed only seasonally. Lately, however, there has been more intensive use, and current studies are testing innovations appropriate to the social and economic circumstances of intensified agriculture, with emphasis on dry-season livestock nutrition.

ILCA is also a network of existing stations and projects with livestock that exhibit resistance to trypanosomiasis. This disease, carried by the tsetse fly, effectively prohibits the development of livestock production in vast humid areas of Africa. The tsetse is responsible for an estimated annual loss of U.S.$5 billion in meat production alone in tropical Africa. Control or eradication of trypanosomiasis could open up 7 million square kilometers in humid areas for grazing by 120 million cattle—double the present cattle population of tropical Africa. ILCA's work in this field complements the immunological research at ILRAD.

HIGHLAND ZONE

The program in the Ethiopian highlands is the most advanced of ILCA's systems studies. Packages of innovations, designed on the basis of research on traditional mixed-farming systems, are already being tested by cooperating farmers under actual farm conditions. The first results are encouraging: milk yields have increased sixfold, while farm income has grown by almost 50 percent. Expanded tests, including critical research on fodder production, animal traction, and sheep production, are now underway, involving two sites in Ethiopia. Meanwhile, mathematical models based on research results are being developed, to be used in the design and extension of further improved livestock production systems.
As the first international center for agricultural research, established in 1960 by the Rockefeller and Ford foundations, the International Rice Research Institute (IRRI) was the prototype for the succeeding centers in the CGIAR system. When IRRI started work in 1962, tropical Asian rice yields averaged less than one-third of those in temperate-zone countries, such as Japan. Under tropical conditions, traditional rice varieties grew leafy and tall; they responded to fertilization and improved management by lodging, or falling over, under the weight of their heavy heads before they could be harvested. IRRI won early, worldwide acclaim for the development and release of IR8, a semi-dwarf, stiff-strawed variety based on Japanese dwarf germplasm. By 1980, about 30 percent of all the rice land in the tropics, and most of the irrigated land, is planted to IR8 or one of the high-yielding, semi-dwarf varieties descended from it.

The success of high-yielding rice from IRRI, popularly celebrated as a "green revolution," has been crucial for Asia, where more than half the world's people live and 92 percent of the world's rice is grown. Worldwide, rice provides more than half the total calories for at least one-third of the world's people, whose lives depend on the annual rice cycle. For them, an abundance of rice means life; a scarcity of rice means hunger and malnutrition, even starvation.

In the process of increasing the rice harvest for these hundreds of millions of people, including some of the world's poorest, IRRI's plant breeders, agronomists, and other agricultural scientists have greatly transformed the traditional tropical rice plant. The improved varieties are not only shorter and stiffer than their predecessors, better able to hold up their grain-heavy heads without toppling, but they also have upright leaves that use solar energy more efficiently and permit denser plantings. They tiller more profusely, producing multiple grain-bearing shoots; they are resistant to harmful insects and diseases and insensitive to day length; they mature in about 110 days instead of 160, enabling many farmers to grow two or even three crops in a season.

The resulting dramatic increases in rice productivity, however, have been limited largely to the minority of rice farmers who have access to irrigation, adequate water control, and fertilizers and other agricultural chemicals. The high-yielding semi-dwarfs are too short for the vast rice-growing river floodplains of Southeast Asia and the Indian subcontinent. Salt-tolerant varieties are needed on the saline soils of coastal marshes and irrigated arid areas. Farmers who grow rain-fed wetland rice or upland rice need drought-resistant types. All improved rices must be resistant to the pests and diseases prevalent in each area; they must have the agronomic and grain characteristics preferred by farmers and consumers in each region. Despite the improvements already made, IRRI and its collaborators face a future filled with challenges.

**GENETIC EVALUATION AND UTILIZATION PROGRAM**

IRRI's selection and breeding program teams scientists from many disciplines to develop improved rice varieties with genetic adaptations for the whole range of rice-growing environments. The Genetic Evaluation and Utilization Program maintains close and collaborative relationships...
with national rice programs in Asia, Africa, and Latin America.

The foundation of the genetics program is IRRI's rice germplasm bank, containing the seeds of some 60,000 varieties, half of which have been tested and evaluated. Each year, IRRI supplies approximately 40,000 seed samples of promising breeding materials and new experimental lines to hundreds of rice scientists around the world. As a result of this program, more than 60 IRRI lines have been released as local varieties by national programs in many countries.

Drawing on the germplasm bank for promising parental materials, IRRI scientists have produced high-yielding varieties with inherent resistance to half a dozen of the most widespread and important rice pests and diseases. The search continues for sources of resistance to emergent strains of pests and diseases, as well as to pests and diseases of local importance.

Other IRRI scientists are evaluating the drought responses of traditional varieties adapted to low-moisture environments in Asia, Africa, and South America. Genes that confer drought tolerance will be incorporated in improved varieties for areas where irrigation is not available. By the same process of selection and breeding, the adverse-soils team is developing new varieties that combine high-yield potential with tolerance for soil salinity, alkalinity, iron toxicity, and deficiencies of phosphorus and zinc.

Floating rices, which have evolved in certain deep-water and flood-prone areas, have the singular ability to elongate their stems quickly to lengths of up to six meters, keeping their heads above rising water. The genetic-elongation characteristic has been bred by IRRI scientists into modern high-yielding varieties, including semi-dwarfs, enabling them to flourish under flood conditions. Some varieties can tolerate several days of total submergence.

In many parts of the temperate zone and the high-elevation tropics, modern varieties cannot be grown successfully; the cool temperatures stunt their growth, producing unfilled grains. IRRI scientists are crossing types selected for cold tolerance with high-yielding varieties, testing the progeny in cold climates around the world. Similar methods are producing heat-tolerant high-yielding varieties for irrigated lands in the arid tropics.

Breeders at IRRI are also converting high-yielding, pest-resistant, well-adapted varieties to a variety of grain types and cooking characteristics, from light and fluffy to soft and sticky, to suit different consumer preferences.

FARM TECHNOLOGY DEVELOPMENT

As well as improved rice varieties, IRRI develops improved farming technologies and systems. A simple, inexpensive applicator developed by IRRI engineers, for example, enables farmers to use fertilizers and pesticides more efficiently by injecting the chemicals below the soil surface into the rice root zone. The device can be mounted on the popular power tiller or on a traditional animal-drawn plow.

Nitrogen, the most important ingredient of commercial fertilizers, is increasingly expensive and unavailable to many

IRRI has designed a more cost-efficient portable power thresher with attachments to reduce the turnaround time between harvesting and planting crops in order to increase cropping intensity.
poor farmers, IRRI soil microbiologists are experimenting with a common aquatic fern, Azolla, that is host to blue-green algae with the ability to fix atmospheric nitrogen into a form usable by plants. Raised by small farmers, Azolla could provide them with virtually free nitrogen fertilizer. For the same reason, IRRI scientists are interested in the evidence that some rice varieties encourage the fixation of atmospheric nitrogen by soil bacteria.

As a necessary complement to the genetic resistance to insect pests bred into some plants, IRRI scientists also develop improved chemical and biological pest-control methods. The institute's researchers have identified spiders that are natural predators of brown plant hoppers and green leafhoppers. They have also experimented with using ducks to keep down field populations of plant hoppers. Therefore—chemical sex-attraction—have been synthesized for use in monitoring populations of pests before they may also, be disrupted by disrupting the pest's mating cycle.

The great potential for further increases through improved production, IRRI maintains a research program on water management. The emphasis of the program is on improving systems for small farmers by developing management methods, reducing water losses, and designing low-lift water pumps.

INTERNATIONAL NETWORKS

IRRI maintains and coordinates several international networks for the exchange of research and improved technologies among scientists in international and national institutions. In the International Rice Testing Program (IRTP), elite varieties, breeding lines, and parent materials from IRRI and national programs are evaluated in 12 yield and screening nurseries around the world. Biologists and economists join forces in the International Rice Agro-Economic Network (IRAN) to analyze the disparity in rice yields between farmers' fields and experimental farms and to identify the factors that lead to the adoption of improved varieties and farming systems by some farmers and not by others. The International Network for Soil Fertility and Fertilizer Efficiency (INFFEE) offers scientists in developing nations the opportunity for systematic evaluation of new formulations and applications of nitrogen, sulfur, and other plant nutrients.

The International Rice Cropping Systems Network develops intensive, double-cropping systems for rain-fed rice. For centuries, rice farmers without irrigation have grown a single crop during the rainy season, letting their land lie idle the rest of the year. With modern varieties that mature one or two months earlier than traditional rice, the farmer who plants his first crop early may still have enough monsoon rain and residual soil moisture for a second crop of rice or some other species. In many cropping systems, harvesting, threshing, and replanting occur...
more than 50 days of the farmer's labor in the prime growing season. IRRI engineers are developing cropping systems and machines to streamline these time- and labor-intensive procedures, reducing the turnaround time to fewer than 10 days and increasing the time available for a second crop. Trials of improved farming systems are managed by cooperating farmers in their own fields, selected to represent important agroclimatic conditions. The results of these trials can be transferred with confidence to similar agroclimatic conditions elsewhere in the world. IRRI's cropping-system research has led to large-scale production intensification in Indonesia, Sri Lanka, and the Philippines.

In the International Farm Machinery Network, IRRI engineers develop inexpensive machinery appropriate to the needs and the means of rice farmers with five hectares or less. The designs are offered at no charge for production and distribution in the developing countries, saving foreign exchange, creating jobs, and building local industry. In Thailand in 1978, local manufacturers produced some 1,600 axial-flow threshers, designed at IRRI to process the extra crop of rice harvested during the monsoon season.
The International Service for National Agricultural Research (ISNAR), established in 1980 with headquarters in the Netherlands, is the youngest of the 13 centers in the CGIAR system. It is also the first center in the system wholly addressed to the crucial institutional elements, rather than the biological and economic factors, in agricultural development in the Third World. As a complement to the work of the other institutions in the CGIAR system, ISNAR responds to requests from developing countries for assistance in strengthening their national agricultural research systems.

The success of the international centers depends ultimately on strong, competent, and active national research programs. By identifying and selecting needs and opportunities for the improvement of crops and livestock and cropping systems in their agroclimatic zones, national programs contribute significantly to the research programs of the international centers. In the actual conduct of research and development programs at the centers, national programs form a worldwide network for testing, selecting, and refining new technologies in the agroclimatic, economic, and social settings for which they are being developed. Finally, national programs have the vital responsibility for adapting new technologies to local needs and conditions, releasing them to local farmers, and vigorously promoting their adoption.

In many developing countries, however, national agricultural programs lack the scientific and technical strength, the organizational and managerial skills, the facilities, and the financial resources to collaborate effectively in research and development efforts. In increasing numbers, senior staff from the international centers have been posted to national programs to cooperate with local scientists. To continue this practice indefinitely would be to divert essential resources from the international centers, while inhibiting the growth of strength and self-sufficiency in the national programs.

ISNAR’S SERVICES

In 1978, a task force including representatives of CGIAR donor members and developing countries recommended that the CGIAR system be expanded by the addition of a service addressed to the needs of national agricultural research programs. In accordance with the task force’s recommendations, ISNAR will offer technical assistance that is unavailable from existing sources, concentrating on problems of program planning, policy, organization, and management. Under appropriate circumstances, the service will also assist in the actual operation of important projects.

Among the services ISNAR will offer are help to governments in identifying research needs, setting priorities, and planning research strategies; designing and installing research facilities and training scientific and administrative staff; and obtaining technical or financial assistance from other sources. As ISNAR becomes fully active and the demand for its services is more clearly defined, practical guidelines and priorities will be established to insure that its resources are used to the greatest advantage.
The role of the West Africa Rice Development Association (WARDA) is to promote self-sufficiency in rice in a 15-country region. For the 150 million people of West Africa, rice is the most important staple food. It is grown on 2.5 million hectares, out of the region’s total land area of 600 million hectares. Most of the population is engaged in subsistence agriculture. Throughout West Africa, however, the agricultural economy is chronically depressed. Rice production is stagnant, changing only imperceptibly from generation to generation, while population and per capita consumption increase steadily.

Despite the region’s ecological potential for producing vastly greater quantities of rice, West African countries regularly spend scarce foreign exchange on imported rice to make up for food deficits. In 1976, West African farmers produced the equivalent of 1.6 million metric tons of milled rice; an additional 0.4 million tons were imported, at a cost of U.S.$131 million. Two years later, the bill for imported rice had increased to an estimated $500 million.

Unlike the other institutions in the CGIAR system, WARDA is an intergovernmental association governed by a council that includes one representative from each member country: Benin, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, and Upper Volta. Established in 1971, WARDA has headquarters in Monrovia, Liberia, and additional research installations in Senegal, Sierra Leone, Mali, and Ivory Coast. To insure that its activities are responsive to local conditions and needs, and to maintain close contacts with member countries, national agencies, and farmers, WARDA has subdivided the West African region into five zones, each of which has a subregional office and staff. Member countries contribute a large proportion of WARDA’s administrative costs, while technical programs are supported by countries and organizations outside the region. Since 1974, the major support for the research program and its associated administrative costs have come from the CGIAR.

WARDA'S STRATEGY

WARDA’s effort to increase rice production in West Africa is based on the concerted, systematic development of improved varieties adapted to the region’s agroclimatic and social conditions. The effort also includes the development and promotion of improved farming systems that are appropriate to improved rice varieties and the agroclimatic, social, and economic conditions of the region.

To insure the controlled introduction of pure, disease-free seed of new rice, scientists treat seeds against seed-borne diseases before distribution throughout West Africa for on-farm testing.
WARDA is working to achieve regional self-sufficiency in rice production. Planting and (below) harvesting rice in Senegal.

varieties for its research programs and for the region, WARDA serves as the sole importer and distributor of seed from outside West Africa through its Seed Storage and Processing Laboratory, at the University of Liberia’s College of Agriculture, in Fendall. Samples of all exotic materials are submitted to the Regional Plant Quarantine Station in Ibadan, Nigeria, which has been expanded with WARDA support to facilitate the safe introduction of breeding materials into West Africa.

WARDA’s activities extend also to the postharvest aspects of rice production, including grain storage and processing, and the marketing of rice for both domestic consumption and export.

RICE RESEARCH
While agricultural research has not been unknown in West Africa, previous efforts have concentrated on cash “colonial” crops to the neglect of cereals, legumes, and roots. WARDA’s research program, financed mainly by the CGIAR, carries out trials of rice varieties and crop-protection systems in different agroclimatic zones throughout West Africa. Germplasm is initially screened and multiplied at the association’s nursery farm at Suakoko, Liberia. Because of its special status, WARDA can design and conduct trials efficiently under all the physical and cultural conditions existing in West Africa, without regard to national boundaries.

Variety trials are carried out in two stages. Initial evaluation tests screen germplasm in all the agroclimatic zones of the region in separate trials for rain-fed, irrigated, and deeply flooded conditions. Promising selections from these initial tests are selected again in the coordinated variety trials for specific adaptation to upland, irrigated, deep-water, and mangrove environments, and to local needs for short, medium, and long duration. The design of the coordinated trials permits variations to include local varieties and treatments. Parallel crop-protection trials test promising insecticides and herbicides under actual farming conditions throughout the region. Superior, well-adapted varieties identified and developed by WARDA’s trial process are already being grown extensively in West Africa. In some cases, varieties developed by WARDA have been further crossed by national crop programs with local varieties to produce specific adaptations to particular local conditions.

RICE DEVELOPMENT
WARDA’s Development Department includes the Seed Multiplication Center, at
Richard Toll, Senegal, which produces foundation seed of improved varieties for distribution to member countries. When its 80 hectares are fully developed, the center will be able to provide 75 tons of foundation seed per year.

The Development Department's experts in agronomy, rural engineering and irrigation, economics and financing, and grain storage and processing work closely with the development agencies of member countries on all aspects of the rice industry, including land use and development, production, processing, and marketing. The department also works with financing institutions to identify, design, supervise, and evaluate rice projects. To expedite the financing and launching of rice-production projects in the region, the Development Department maintains a catalogue of proposed and ongoing projects and acts as an intermediary between prospective financing institutions and member countries.

TRAINING, DOCUMENTATION, AND COMMUNICATION

Training is an important component of WARDA's activity, and the training center, which is located at the University of Liberia's College of Agriculture in Fendall, organizes several courses, for example, rice production, rice processing, water management, seed multiplication, and certification every year for rice specialists and prospective rice-specialists from 15 member states. The training department is also responsible for arranging postgraduate courses in universities within and outside West Africa for selected graduates from member states and junior scientists of WARDA.

The documentation division is responsible for the collection and preservation of publications related to rice production and the protection of other related food crops in the tropics. Since WARDA is a bilingual organization, the communication department plays an important role by ensuring that documents related to rice production are available to interested workers in both English and French and also by publicizing the activities of the organization in the member states of WARDA.