INTERNATIONAL RESEARCH IN AGRICULTURE

International Rice Research Institute (IRRI)

International Maize and Wheat Improvement Center (CIMMYT)

International Center of Tropical Agriculture (CIAT)

International Institute of Tropical Agriculture (IITA)

International Potato Center (CIP)

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

International Laboratory for Research on Animal Diseases (ILRAD)

International Livestock Centre for Africa (ILCA)

Consultative Group on International Agricultural Research
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Providing sufficient food to meet the needs of an ever-increasing world population is one of the greatest challenges mankind has ever faced. Although there are signs that efforts to slow down the rate of population growth are beginning to have success in some countries, and although the process of development itself eventually leads to slower growth, it is an inescapable conclusion that the world’s population will double by early in the next century—and that of the developing countries will probably double by the year 2000. Food production must therefore be doubled in the same short time span just to maintain present-day levels of nutrition—and more than doubled if these standards are to be improved for the many millions of now undernourished people of the world. Most of the increase must come from the developing countries themselves, where food production and nutritional levels are low, and most of it must come by increasing the productivity of land already under cultivation.

This booklet describes initiatives which have been taken by the international community to spearhead the agricultural research and training which is an essential element in achieving this goal.

The purpose of the booklet is to bring to the attention of interested policymakers, agricultural specialists, and laymen the work being sponsored by the Consultative Group on International Agricultural Research (CGIAR). It describes the purposes, structure and operations of the CGIAR, and the autonomous international research and training programs (presently numbering ten) which it supports. It provides ready reference to the specific activities carried out by each Center, so that those who are most directly concerned know where to turn for further information or to initiate collaborative work.

The first chapter provides a general introduction to the structure, purpose and operations of the CGIAR and briefly reviews the historical background of international agricultural research efforts as they pertain to developing countries. The remaining chapters are devoted to concise, descriptive accounts of the work of each of the institutes.

At a time when the provision of sufficient food supplies is an overriding concern of the world community and above all a day-to-day problem for hundreds of millions of people, there are still many places in the world where men till the soil in the primitive manner of their ancestors a thousand years ago. As co-sponsors of the CGIAR, the Food and Agriculture Organization, the United Nations Development Programme, and the World Bank recognize the
enormity of the task that lies ahead. But they are confident that the Consultative Group is providing the international community with some of the tools required for new solutions to this most urgent of the world's problems, and that the research programs it sponsors are bringing new methods and higher yields to farmers in developing countries, more food to the hungry, and a better start in life to the world's children.

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INTRODUCTION

On November 1-3, 1973 representatives of 29 governments, assistance agencies, foundations, and developing regions of the world met in the board room of the World Bank in Washington. They were there to try to put together $34 million for 1974 support of international agricultural research. They did marshal the money, up from $15 million in 1972 and $23 million in 1973. They also launched the seventh and eighth in a series of strategically located, new types of research and training centers, as well as supporting the program of rice trials which the West Africa Rice Development Association was undertaking in its 14 member countries. In November 1974 the Group met again in Washington to mobilize the $45 million needed in 1975 to press on with the research and training programs of the eight centers, and also to launch a ninth center and a new international program to collect and preserve the world’s plant genetic resources. Some 200 senior scientists, together with support staff, are now engaged in the research programs of this international network.

The events that led to the formation of the Consultative Group on International Agricultural Research (CGIAR) are unique in agricultural history. This booklet explains what the international agricultural centers are; what they do; why and how they came into existence; how they are governed and staffed, and how financed; how priorities are set, and proposals submitted and screened; how the supporting donors and their advisers operate; what benefits the international centers have brought and will bring to the developing countries; and how they relate to agricultural research at regional and national centers.

Most farm families of developing countries are dependent for food and minimal income upon meager crop yields from long-impoverished soils. Many are subsistence farmers in areas remote from centers of commerce. Their per capita incomes are commonly low—well under national averages of $100-200 a year, far below the $3,900 average of the U.S. The subsistence farmers who depend for their livelihood on the basic food crops—cereal grains, root crops, food legumes—have been among those with the most desolate future. While governments or commercial companies have supported research for plantation crops (rubber, sugar cane, bananas, pineapple, to name a few), there had been little such attention until the 1960s to the improvement of the basic food crops in the developing countries. Yields of rice, wheat, corn, barley, sorghum, millet, field beans, chickpeas, pigeon peas, cowpeas, cassava, yams, sweet potatoes, and farm animals remained low and static at the levels of decades or centuries past.
THE INTERNATIONAL INSTITUTES
THE EVOLUTION OF THE INSTITUTES

It is hoped that the era of neglect of the food farmers of the developing countries is coming to an end. There is encouraging evidence that countries can make significant progress in small-scale agriculture with the development of new technology and new types of development assistance. For instance, in Mexico by the early 1960s, the necessary technology to improve Mexico's main food crops had been worked out by scientists under technical assistance arrangements with the Rockefeller Foundation. Hundreds of technical personnel were trained and government and private sector institutes were strengthened.

At the same time, it was realized that little was being done to improve rice yields for the people of tropical Asia, although rice was and is the staple food of most of Asia's millions. But there were no prospects that each nation could have a team of research scientists after the Mexican model. There were simply too few capable scientists available in Asia, and it would have been too expensive to supply them to each country from outside. The idea was developed of having one privately organized institute which would be international though sited in one location. The Rockefeller and Ford Foundations, after discussions with the Government of the Philippines, agreed to create a totally new type of institution, to be located at Los Baños in the Philippines. This was an international, nonprofit, research and training institution with an international staff. It is governed by an apolitical, self-perpetuating board of trustees with a majority of the members being eminent citizens of the nations to be served. The initial staff of 18 consisted largely of young scientists who came from eight different countries. The research staff of the International Rice Research Institute now numbers about 40 scientists, two-thirds of whom are from countries of Asia.

The record of IRRI is 12 years of solid success. By 1965 its breeding program had created a sturdy dwarf rice, IR 8, which, when properly fertilized and watered, gave very high yields. This variety has been succeeded by newer varieties which combine high yields with good eating quality and with resistance to the most important pests and diseases that attack rice.

With the aid of the Ford and Rockefeller Foundations, an international center for the improvement of maize and wheat (CIMMYT) was established in Mexico to continue the work of Mexican and Foundation scientists. Later, again with the aid of the Foundations, an international institute for tropical agriculture was established in Nigeria (IITA) and an international center for tropical agriculture was established in Colombia (CIAT). Today, eight international agricultural research centers, each located in a developing country and each applying its skills to regional and global agricultural problems, are supported by CGIAR. They are:

1. The International Rice Research Institute (IRRI), Los Baños, Philippines, one of the two oldest international centers and the one which served as a prototype for those that followed;
2. The International Maize and Wheat Improvement Center (CIMMYT), El Batán, Mexico, whose success in developing new strains of wheat and
high-lysine maize has already had dramatic impact on developing country production;

The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, focusing on farming systems for the humid tropics, mostly in Africa, with special attention to the use of tropical soils;

The International Center of Tropical Agriculture (CIAT), Palmira, Colombia, a pioneer in effective farming systems for lowland tropical areas of the Western Hemisphere;

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India, which stresses farming systems and water conservation methods of particular benefit to small-scale farmers in hot but water-short regions;

The International Potato Center (CIP), Lima, Peru, a one-crop institute working to expand potato cultivation in developing areas;

The International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya, one of the newest centers, currently concentrating on immunological methods for controlling two major animal diseases—East Coast fever and trypanosomiasis;

The International Livestock Centre for Africa (ILCA), to be located in Ethiopia, also new, and also working to increase animal production in the developing world through improved animal husbandry techniques.

In addition, the CGIAR has sponsored the establishment of the International Board for Plant Genetic Resources headquartered in Rome and serving as a clearing house for the collection and exchange of genetic resources in agriculture. The Board, an outgrowth of recommendations made by the Stockholm Conference on the Human Environment, coordinates the cataloguing efforts of various national and institutional gene banks and certifies that the exchange of genetic materials is disease-free. It also works to preserve genetic resources in danger of extinction.

Regionally, the CGIAR is also supporting the rice research program of the West Africa Rice Development Association (WARDA), an international organization of West African governments.

The concept of an international center is that it should be international, though situated in one location. It should be owned by and governed by an international board of trustees. Its senior staff should be recruited from the most able scientists in the world without regard to nationality. The host government should make suitable arrangements to enable the center to develop the facilities, including buildings and experimental farmlands, that it needs to carry out its research program. The center should have among its objectives not only the carrying out of its own research but also the development of strong linkages with national and regional research institutions in other parts of the world, and it should also have responsibility for training research scientists and production workers.
The international centers have extremely close relations with the countries in which they are situated, and they develop joint research programs with national researchers in the host countries. Most centers are situated near a university with which joint scientific programs and training can be worked out. The research on which an international center is engaged is mainly directed to one or more specific food crops and to the development of farming systems of which these food crops are an integral part. IRRI, for instance, researches on rice and on multiple-cropping systems including rice. CIMMYT works on wheat and maize and also has a small but important program on barley. In each of the centers, the research programs are tackled by multidisciplinary teams of scientists including plant breeders, geneticists, soil scientists, agronomists, entomologists, pathologists, and others. Part of the outstanding success which these workers have already achieved in the older established centers is due to the facilities they have for working with an enormously wide range of genetic material. In some programs hundreds of thousands of crosses can be made and tested in a single year. In addition to the development of many crop varieties giving greatly increased yields, attention is paid to food quality, agronomic and fertilizer practices, crop rotation, maintenance of soil fertility, and in some centers to problems in the mechanization of small farms. All centers have economists as members of their research teams.

An international center is expected to develop an outreach network which links it with research centers in other countries through programs of assistance or collaboration. The center will build up a library and often provide documentation services for scientific workers in the fields of concern to the center. Conferences, seminars, and workshops are organized to provide occasions when international scientists can meet to discuss findings. Most of the international centers are in the process of building up collections of the world's germ plasm for the crops for which they are responsible.

The size of the budget of an international center varies according to its scope of work. Centers have needed between $5 and $20 million for developing their buildings, laboratories, greenhouses, experimental farmlands, and housing for staff and trainees. Annual operating budgets are at the level of about $5 million. Because of the need to establish additional international centers once the effectiveness of the first had been demonstrated, the financial requirements grew far beyond the capacity of private foundations to meet them. New funding arrangements became necessary, and the Consultative Group on International Agricultural Research was formed in 1971, after many preliminary discussions among potential donors.

**BACKGROUND ON CGIAR**

The CGIAR is simply a group of donor countries, development banks, foundations, or agencies which accept a commitment to provide funds for international agricultural research. The sponsors of the Group are the World Bank, the Food and Agriculture Organization of the United Nations, and the United
Nations Development Programme. In addition to the three sponsors, the members of the Group in August 1974 included: 13 governments—Australia, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Japan, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and the United States; three regional development banks—the African, Asian and Inter-American Development Banks; the Commission of the European Communities; three private foundations with an impressive record of achievement in agricultural research—the Ford, Rockefeller, and W. K. Kellogg Foundations; and the International Development Research Centre, an autonomous Canadian organization.

The five major developing regions of the world participate in the Consultative Group through representatives designated for a two-year period by the regions at FAO's Biennial Conferences. Each region—Latin America, Africa, Asia and the Far East, Southern and Eastern Europe, and the Middle East—has designated two countries which alternate as members at their own discretion.

The members of the Group usually attend meetings in Washington at the World Bank's headquarters twice a year. On the basis of reports of progress from existing centers and on needs for new research thrust, the members agree to provide funds. A member of the Group is free to provide funds for some centers and not for others; most international centers attract funds from several of the donors; none attracts funds from all donors.

The Secretariat for the Consultative Group is provided by the World Bank from its headquarters in Washington. The Group operates in a rather informal atmosphere and without much red tape. It is expected that additional donors will join the Group in the future.

THE TECHNICAL ADVISORY COMMITTEE

The Consultative Group is advised by a Technical Advisory Committee (TAC) consisting of 13 eminent scientists and economists. Apart from the chairman, the members are drawn equally from developed and developing countries. TAC advises the Consultative Group on research priorities, on specific research proposals for which Group assistance may be sought, on the effectiveness of existing international agricultural research programs, and on how best to organize and conduct this research. One of TAC's first tasks was to review research needs in developing countries and recommend priorities, taking into account not only the technical requirements of increased agricultural productivity but the ecological, social, and economic factors as well. TAC recommended that priority be given to research on the important food crops of the tropics and subtropics with attention also to cattle production in Africa and Latin America.

Although the international centers truly are international in scope, they also tend to have a particular affiliation to the region in which they are situated. In 1974 TAC has recommended to the Consultative Group that a new interna-
tional center be established to carry out research into crops that are important in the Middle East and northern Africa, including barley and certain grain legumes, and on farming systems including livestock raising and water management. This will fill what seemed to be a gap in the geographical coverage of the international centers.

The Secretariat for TAC is provided by FAO at its headquarters in Rome. TAC usually meets two or three times a year in Rome or Washington. Members of TAC familiarize themselves with the work of the international centers and with research needs of developing countries by visits to international, regional, and national centers.

In order to concentrate on priorities and to achieve the necessary focus in objectives, CGIAR and TAC have to be selective in deciding their support for international research. Proposals for new research centers or programs have to be channeled through a member of the Consultative Group or through one of the sponsors. It is not possible for CGIAR to respond to requests to support national research programs, but the linkage between international and national research institutes is recognized as being of great importance. Methods of strengthening this linkage and of making the research work of the international centers pay off on the farmer’s fields are accorded high priority, as is reflected in the following chapters on the activities of the international centers.

A vital transformation of agriculture in the tropics is what the international centers, collectively, are trying to achieve. It is a transformation which involves not only new seeds capable of producing higher yields but a whole package of related agronomic practices—when and how much to plant and at what spacing and depth; if, when, and how much to irrigate; the kind of fertilizer required; when and in what amounts to apply it; the method of weed and pest control, and so on. It also involves new government services and new government policies, such as credit and marketing arrangements, technical advice, storage facilities, and other measures. And it requires a continuous process of scientific research and testing.
As the first of the international centers to be officially established, and the first to be wholly planned from the ground up, the International Rice Research Institute (IRRI) is often cited as the prototype of the international agricultural research institute. Early in its development, it won celebrity when the release of a new tropical high-yielding rice variety named IR 8 led to a successful campaign to raise yields in the Philippines, then in other countries of the Asian rice belt. Within a limited sphere, the effect was dramatic. A minor cultural revolution, as significant as the unprecedented rice yields, took place on the heels of technological change. Farmers not only caught on to the new rice-growing methods—the “package of practices” that made the new seed perform prodigies—but in an analogous leap across barriers of time and tradition, they quickly absorbed the motives and attitudes of the modern producer and entrepreneur. This rapid telescoping of cultural and social evolution took the international assistance community somewhat by surprise, and brought about some strenuous rethinking in the field of developmental programming. IRRI’s experience—scrutinized for lessons and guidelines and scanned for possible mirage—influenced the subsequent formation of the other agricultural institutes; it helped determine their nature, their staffing patterns, and the directions their programs took. One of IRRI’s primordial strengths was its single-minded focus on rice.

REMODELING RICE

Rice is the overriding preoccupation of a large proportion of the world’s people. For Asia’s poor, rice is virtually synonymous with food. It provides a livelihood for hundreds of millions; its growing cycle rules their daily lives, and an abundance or scarcity of it is a measure of their well-being.

Rice is likewise the central concern of IRRI’s rice researchers, production specialists, engineers, and communications experts. The technological improvements that doubled yields were developed by interdisciplinary teams concentrating primarily on genetic manipulation of the tropical rice plant. Agronomists, physiologists, plant pathologists, entomologists, and geneticists worked together to produce a high-yielding rice that would feed more people from the same land. Its
stature was changed from tall to short; its stem was strengthened so that it could absorb more fertilizer and produce heavy heads of grain without toppling over; short, upright leaves made better use of solar energy and allowed for denser stands; genes for disease and pest resistance were bred in and sensitivity to day length was bred out; and the growing season was reduced from about 160 days to just over 100, enabling the farmer to grow two or even three crops a year, or to follow his rice harvest with another food crop. The new rice plants tillered readily: they would send up extra shoots wherever they found room, which meant that with the right stimulus, every seed could give a bonus yield of grain.

This remarkable plant-breeding feat was made possible by the collection and screening of thousands of rice varieties from the Philippines, Japan, and other Asian countries, plus a number of cultivars supplied by the United States Department of Agriculture. IRRI’s genetic resources bank currently counts over 30,000 accessions; over half of these have been described and their significant traits recorded. Each year IRRI supplies new lines to rice breeders around the world; in a typical recent year over 10,000 seed samples were sent out to scientists in 69 countries. At least 33 genetic lines developed and tested at IRRI have been released and given local names in other countries. About half of the Institute’s work now involves evaluating genetic resources and sending out breeding materials in response to requests from national programs and rice scientists in different countries around the world.

PACKAGED TECHNOLOGY

But IRRI’s goal was not simply to produce new rices and find the optimal conditions for highest yields; it was to raise production levels of the rice-growing countries of Asia. Therefore, as soon as the research program began to show results on the experimental plots, the Institute set about developing extension and demonstration techniques to get the new seed growing in farmers’ fields and to teach them how to handle it and protect it to get the best results. This work led to the invention of the famous “package of practices”—a concept that is both literal and figurative. A rice-production kit was prepared, consisting of two to five kilograms of seed and the necessary amounts of fertilizer and insecticide, plus instructions for their use in the course of the rice-growing cycle. The invisible part of the package was institutional support, which meant technical assistance and follow-up from the extension agent, who had the resources of IRRI available to him. In some areas use of the package gave the farmer access to credit through governmental programs and a guaranteed selling price. In the early days, the field worker himself may have taken a course at IRRI; later on he was more likely to have been taught his job by a production specialist who had spent six months to a year in one of IRRI's training programs.

IRRI’s first ten years left an indelible mark on rice production in Asia and to some extent in Africa and Latin America; it also saw the charting of a new course in institutional development. IRRI’s impact has been decisive, and its reputation for excellence has
Scientists seek resistance to plant enemies.

been a practical asset in generating interest in the new rice technology. Nonetheless, a host of problems remain to be solved.

FOCUS ON THE PRODUCER

Under the banner of 'getting out of the experimenter's field and into the producer's field,' IRRI has taken on the challenge of bringing modern methods to the small farmer, a commitment that involves, prominently, improving upland and rainfed rice culture. Admittedly this is going to be a harder pull than the work with irrigated rice, and the results are likely to be less rapid and less spectacular. The significance of the effort, however, is unparalleled, since the quality of life of millions of Asia's poorest farmers is in the balance. Upland and rainfed rice accounts for 65 to 70 percent of the world's rice lands; yields average 1.0 to 1.5 metric tons per hectare.

Exploratory studies suggest that the constraints in these rice-growing areas come from man as well as from nature, and broad strategies are being drawn for a concerted attack on socioeconomic as well as technological barriers to better yields and higher farm income. An economist, a sociologist, and a climatologist will cooperate with IRRI's teams of rice breeders, agronomists, and soil scientists in efforts to develop farming systems for a variety of environments, with special attention to the farmers who were bypassed by the first wave of advances set in motion by the Institute's new technology. Socioeconomic studies have been undertaken at 14 locations in six countries to discover why the new methods have not found wider acceptance among producers.

In all, only about 20 percent of the rice land in South and Southeast Asia is now planted to the high-yielding rices (as much as 50 percent in some areas, but less than 1 percent in others). If there were more high-yielding varieties adapted to a wide variety of conditions, such as moisture regimes, growth durations, and deep water, more farmers would adopt the new varieties.

High-yielding varieties, such as IR 20 and IR 26, which give up to 10 metric tons per hectare in experimental plots, average only four to five tons in farmers' fields. (On the whole, that is not a bad showing, considering that overall average rice yields for Asia's developing countries are reported to be 2.0 to 2.22 tons per hectare.) The reasons for this variance
of the yields of IRRI rices in farmers' fields as compared with those of experimental plots include lack of pest and weed control, inadequate or unbalanced nutrients, and unreliable water supplies. IRRI scientists are taking steps to identify specific aspects of these constraints for which practical remedies can be found. For example, a study of Thai farmers revealed that some were neglecting to follow fertilizer recommendations, others were not weeding properly; in both cases, yields were depressed, but when the two measures were given attention rice harvests met expectations and profits went up.

RESEARCH PRIORITIES

Top priority in research goes to plant protection. IRRI’s varietal improvement teams are concentrating on the search for genetic resistance to a wide range of plant enemies, including rice blast, bacterial blight, bacterial leaf streak, grassy stunt, tungro virus, and the insect carriers of the last two, the green leafhopper and brown planthopper. They have identified sources of partial resistance to each of the major rice enemies and have bred experimental lines that combine resistance to as many as six to eight of them.

This research, in part, reflects IRRI’s concern to produce new kinds of high-yielding varieties for low-income farmers, whether they grow rice under irrigation or in upland or rainfed areas; usually the small producers operate at subsistence level and cannot buy insecticides. Plant protection built into the seed is a money-saving feature that may persuade them to choose a high-yielding variety and thus take the first step out of the subsistence-poverty trap. The use of new and cheaper chemicals and techniques for controlling insects is being studied as well; for example, the placement of selected pesticides in the root zone of the plant in a single application has been found to be superior in effectiveness and safer than conventional methods of repeatedly spraying the pesticides on the plant.

Another aim is to produce plants that will give good results using less fertilizer. IRRI’s soil microbiologists have found that rice plantings have a much higher nitrogen-fixing effect than was formerly believed. Soil chemists have identified certain mineral deficiencies in the different rice-growing regions, and correctives are being sought, both by supplying the missing elements and by breeding plants that have inherent tolerance to various adverse soil conditions.

The curious ability of deep-water rices to adapt to the level of flooding is a possibility for breeding into IRRI lines; an “elongation gene” permits dwarf rices to grow taller if the field water level rises.

Rice protein quality and amino-acid balance are being stressed, in the hope of breeding more nutritive strains. Rice varieties that have 9 percent protein on a milled basis are being developed (ordinary rice has 7 percent), and they have shown good results in feeding trials with animals. Two rice varieties with .5 percent higher-than-normal lysine levels have also been identified, out of several thousands screened.

Improved water delivery is being studied in areas where irrigation systems are not having the desired re-
sults. Investigations on a pilot basis are being carried out by IRRI to learn how to maximize the efficiency of distribution systems serving small farms. Sociologists in the Philippines are looking at the farmers’ use of irrigation water and their stake, as they perceive it, in improving local networks of ditches and in having a voice in community water management. IRRI’s experience seems to indicate that dams and canals built by donor agencies fall short of their purpose unless the program includes follow-through to the level of on-farm delivery of irrigation water and stimulates active involvement of the local people.

Small-scale machinery with simple replacement parts is being designed by IRRI’s engineers; it can be manufactured by local labor and sold at approximately one-half the cost of other equipment; repairs are also cheaper and less complicated. Low-cost threshers, hand tractors, and grain driers have been built by IRRI’s engineers and released for local manufacture and distribution. The paddy-seeder designed for small-farm use permits direct seeding and plowing and rapid tillage (as contrasted with the traditional tedious methods of hand planting the seedlings). Such machines, far from cutting down on manpower needs, actually create employment. By using the short-season rices and aided by machinery, the farmer can harvest two crops a year, whereas he used to get only one. That way he can nearly double his production; but to do it he needs more hands at planting, weeding, and harvest time. Thus, the short-season rices and the newly introduced system of cropping several crops per year create the demand for machinery. Machines developed by Institute engineers have been tried out in cooperative programs in nine countries.

**EDUCATIONAL PROGRAMS**

IRRI’s educational programs are the nerve center of an expanding system of ties with rice-growing efforts around the world. Training at several levels is offered; very much in demand from the start has been the rice production course offered to candidates from extension organizations and research and educational institutions, chiefly from South and Southeast Asia. This six-month intensive training program has proven so useful that, from training production specialists in IRRI-developed technology, it rapidly progressed to training teachers who would organize and carry out training programs, based on the IRRI tech-

*Field days demonstrate modern farming methods.*
niques, in their home countries. The course consists of half classroom study and half field experience and accommodates about 35 candidates at a time, with a typical class representing up to 15 Asian nations. A special five-month course in multiple cropping is also offered.

Classes are conducted in English, and for those who want to brush up their language skills, there are do-it-yourself courses on records, permitting them to advance at their own pace. Although not all the students plan to work in extension, they are exposed to every aspect of rice research and production—the different rice varieties, insect and disease problems and how to deal with them, use of herbicides and pesticides, experimental procedures, statistical analysis, and even institutional and administrative problems. They learn how to conduct field demonstrations and explain the new technologies to farmers. An important feature of the training is learning to work in interdisciplinary teams, typically made up of an agronomist, a plant pathologist, an entomologist, an economist, and a communications specialist. The plan is to have them replicate the team approach in their own countries, thus perpetuating a concept that has been one of the keys to IRRI's success.

Formal academic training for scholars and fellows—M.A. or Ph.D. degree candidates and young scientists specializing in some aspect of rice research without aiming for a degree—lasts from one to two years and is conducted in cooperation with the College of Agriculture of the University of the Philippines. About 60 to 65 students at this level are in residence at a time. Those conducting their thesis work in connection with one of IRRI's programs can be at the Institute in five minutes from their classrooms at the College. Postdoctoral researchers, special trainees, and visiting scientists add to the roster of those who have benefited from contact with IRRI's expert staff and access to its experimental facilities.

In all, about 700 man-years of training have been logged since the Institute's establishment, and graduates of the various programs have fanned out over most of South and Southeast Asia—and some as far as Africa and Latin America—to conduct local training programs, plan and administer rice research and production efforts, and oversee developmental projects from key posts in government ministries, research centers, or international organizations.

**INTERNATIONAL ASSISTANCE**

IRRI's international commitments have expanded as word of its successes has spread throughout the rice-growing countries of the developing world. Within the international-institutes system, major responsibility for rice work in Africa is delegated to IITA; and in Latin America, to CIAT. Rice scientists gather periodically at Los Baños for symposia on technical problems; a number of scientific publications, including a detailed annual report of research results and other activities, and an extensive bibliography of rice literature updated yearly, are sent out to interested institutions and individuals; and the library at IRRI has an active documentation
from these highly varied environments has been an invaluable component of the Institute's central research program. Varieties developed in these Asian countries can be useful for adaptations in Africa, the Near East, and Central and South America, wherever IRRI's help is requested.

In the Philippines, IRRI has cooperated closely with government efforts to increase rice production, most recently in the training of production specialists for a new program called "Masagana 99" and its sequel, called "Masagana 99-2." A 28 per cent increase over the 1972 rice crop was achieved in the 1973-74 Masagana 99 program; it was the largest annual rice production in the history of the Philippines.

Many of the national centers are able to take over full responsibility for research and development programs within their own countries, and to continue cooperative research with IRRI on a self-sustaining basis, thus releasing Institute scientists for assignment to new programs. IRRI's policy has consistently stressed development of strong national programs with built-in problem-solving capability; in entering into assistance agreements, the Institute expects its participation to follow a curve of increasing, then diminishing involvement, until the local program emerges as an independent entity. The national units will ultimately be able to cooperate with each other on a footing of equality, in addition to maintaining contact with IRRI for research, varietal testing, and exchange of scientific information at the international level.

With increasing emphasis on stimulating initiation of research and
production work at the national level focused on small farms and farming systems, more decentralization of IRRI's assistance is foreseen for the future. This trend is dictated in part by the nature of the technology to be developed: in contrast with the widely adapted high-yielding varieties and packages of practices, whose uniformity was one of their outstanding assets, farming methods for rainfed and upland rice and associated crop-combination systems are expected to show wide diversity, in conformity with differing agroclimatic, socioeconomic, and even political conditions in the selected localities.

Multiple Cropping

A central dynamic in this effort is IRRI's experimental work in multiple cropping systems. This program has attracted worldwide notice for its demonstration of the high food-production levels that can be achieved in the tropics and subtropics under controlled experimental conditions, using the new short-season rices in combination with other crops commonly grown or easily adapted in these latitudes.

Inter-cropping, relay cropping, and various rotations were tested, and the best-performing combinations were sought, not only in terms of maximum yield, but for interactions affecting insect control, weed infestation, soil toxicity, use of nutrients, and similar factors. For example, maize intercropped with sweet potatoes, mung beans, or peanuts was found to be a successful combination, each for a different reason. (Maize growing may prove to be an unexpected boon to confirmed rice eaters in times of high prices or shortages: a study made during 1973 showed that poor families were using corn grits mixed with rice and found it a satisfactory substitute for the more costly pure rice.) Sweet potatoes planted in relay with rice (the potatoes going in three weeks before the rice was harvested) resulted in good yields of both crops; mung beans in rotation with maize prospered, but mung beans following mung beans did poorly.

This kind of highly specific information, developed under the ideal conditions of IRRI’s trial plots, will provide valuable backstopping for the projected farming-systems program. Alternate combinations of crops tested at IRRI can be recommended for given soils where yields of rice or other traditional crops are low, or where rice growing is dependent on the rains, and the fields ordinarily lie fallow the rest of the year.

Rice, since IRRI began work a decade ago, has proven itself extraordinarily responsive to the efforts of modern science, and rice growers as well as their leaders in government, have shown themselves equal to the challenge of putting the new technology to use in the interests of feeding growing populations. As demand grows, IRRI's experience with rice and with the people who grow it will be invaluable in helping build strong national programs in the many countries where better rice farming can form the basis for raising the living standards of large numbers of people.
INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

Londres 40
Mexico 6, D.F.

The International Maize and Wheat Improvement Center (CIMMYT) is one of the oldest and most prestigious of the international institutes. Its research base had been evolving for over 20 years under a collaborative agricultural program between the Rockefeller Foundation and the Mexican Government, and assistance to countries in Central and South America and Asia had already been undertaken by its staff, when it was reorganized as an international center in 1966. Through an agreement with the Government of Mexico, it assumed autonomous status under an international board of directors and began systematic expansion of its research, training, and communications activities.

Almost tangible in CIMMYT's dynamics is belief in change. In its short existence, the Center has witnessed sharp changes in grain and in men—its leaders communicate a confidence more persuasive than zeal, that traditional agriculture can be changed and is changing; that planners and policy makers can be swayed; that farmers will adopt new technologies and that their horizons can be widened and their material circumstances improved. And it is a fact that after the discoveries of the past 15 years, maize and wheat will never be the same.

A GLOBAL MANDATE

Since its official establishment, CIMMYT has developed its research and training in patterns of give-and-take that reach out to nearly every major wheat and maize-growing country in the world; it has collaborated in agricultural projects in developing countries and has consolidated ties with research and educational institutions in the advanced nations. Today the Center's activities include evaluation of genetic resources, breeding and testing of new grain varieties, agronomic research, biochemical and nutritional analysis of grain protein, assistance with production programs and consultation on agricultural policies, war on plant diseases and pests, training of future wheat and maize specialists, exchange of scientific information, and development of new educational techniques and materials.

But while CIMMYT's mandate is global and its current operations virtually worldwide, its center of gravity is the research and training programs in Mexico. That is where the wheats behind the record-breaking harvests
in Asia were developed; where experimental populations of high-protein maize are being worked on around the calendar to produce viable crop varieties; and where triticale, the first man-made grain species, has been nurtured and developed to the level of a competitive commercial crop. CIMMYT's wheat and maize research has also generated programs on related crops like barley and sorghum.

Crop improvement is the primary objective, but its ramifications are far-reaching. Genetic manipulation of the wheat and maize plants for higher yields and better agronomic performance entails refinement of management techniques and productivity systems; a search for new experimental approaches and more precise statistical methods; closer coordination of scientific projects and exchanges of information and biological materials among the world's wheat and maize workers; and development of ways to reach and persuade farmers in the use of new technologies. These several efforts converge toward the ends of bettering the farmer's economic prospects and upgrading the quality of country and village life in the wheat and maize-growing areas of the developing world.

In its first annual report, CIMMYT professed a plain and unequivocal goal—but one with implications of such complexity and magnitude that its bounds have still to be set:

*The main purpose of CIMMYT is to assist nations throughout the world to increase the production of wheat and maize. . . . Priority will be given to those countries that need and request help in increasing yields.*

Today food-supply prospects and population growth projections are such that the need for help with varietal improvement and production programs is nearly universal in the developing countries, and requests for aid arrive at CIMMYT headquarters more frequently than the Center can respond. In 1974 CIMMYT staff members were stationed overseas to work in wheat programs in Turkey, Tunisia, Algeria, and Lebanon; maize specialists were assigned to programs in Pakistan, Nepal, Egypt, Zaire, and Tanzania. Consultation is being provided annually to as many as 60 countries of Asia, Africa, and Latin America.

In 1973 wheat and maize specialists in 91 countries grew sample batches of experimental lines at 1,429 trial sites in CIMMYT's systematic international programs of trial nurseries. These tests are aimed at developing superior grains, screening them for resistance to diseases and pests, and adapting them to growing conditions in both promising and unpromising spots, where they may eventually add to the food supplies of underfed populations, give farmers more stability in precarious economies, and help tide them over in hard times. Both wheat and maize programs plan expansion of their overseas efforts in countries requesting aid, a move that will mean an increase in staff on foreign assignment as well as extension of consultation services and technical support to national and regional agricultural institutions and foreign governments. CIMMYT's assistance to developing countries is aimed primarily at strengthening national agencies so that they can contribute to increas-
ing production at home and also form part of the international problemsolving system.

TRAINING PROGRAMS

Training at CIMMYT provides concrete backstopping for this effort by annually increasing the number of wheat and maize scientists active in the developing world. The training programs have formed a growing cadre of wheat and maize specialists—loyal alumni who now staff national and regional agencies and lead research, education, and extension efforts all over the tropics and subtropics. These graduates keep in touch with the Center's research and are often instrumental in expanding its overseas network of adaptive research on new lines of maize, wheat, triticale, and other grains; moreover, they know they can turn to CIMMYT's experts for advice and help with the problems they come up against in their own countries.

Young maize scientists come from many parts of the world.

The number of trainees in wheat production and in maize production is about 100 a year; studies last from six months to a year and are geared to the formation of intermediate-level research and extension specialists. Candidates are given field experience with wheat or maize production, sprinkled with a small amount of classroom instruction, to prepare them to train teams of production specialists, extension agents, and subprofessionals in their home countries, thus creating an expanding corps of field workers to answer the needs of thousands of farmers engaged in both large and small operations.

Teamwork is a hallmark of the CIMMYT work code, and it is reflected in the training program. One approach used involves five-man teams, representing five different disciplines, often from five different nations, and as likely as not receiving support from as many or more donor agencies. They attack grain production problems and learn at firsthand how to conduct coordinated, interdisciplinary research. In this way, the integrated approach is automatically built into the future training programs of the cooperating organizations, since each man will return to a different nation to teach CIMMYT's methods to his countrymen.

Postdoctoral scientists, too, work on problems associated with CIMMYT's assistance work in their home countries; they conduct research and take part in the training of field technicians—there is no faster way to learn the techniques of adaptive research and production, say CIMMYT's experienced scientists, than by having to teach others.
In Central and South America, and parts of Africa and Asia, large numbers of rural people live chiefly on maize, most of them poorly. It is also one of the principal grains raised for animal feed, both for large commercial livestock and poultry operations and for the few animals raised on the subsistence farm. But even with world maize production currently reaching over 300 million metric tons, there is not enough to go around.

Maize production gains trailed behind rice and wheat in the peak production years of the late 1960s. Maize is an extremely versatile crop, and this quality is both a strength and a weakness. Because of its sensitivity to environmental conditions and to day length, a specific combination of traits is necessary for optimal growth in any given locality. Over the centuries, thousands of lines were evolved by farmers whose survival depended on selecting the best-performing strains and perpetuating them. A wide range of color, size, and texture in the grain; special milling or cooking qualities; and other variations fancied by people of different backgrounds and cultures also influenced the configuration of traits in the maizes handed down from remote forebears.

In setting out to increase maize yields, CIMMYT began by collecting these tropical varieties from South and Central America; with later additions from other latitudes and other continents, the total world collection assembled at CIMMYT now numbers over 12,000. Breeders aimed first at development of high-yielding, disease-resistant lines that could serve as a basis for further research in the different maize-growing environments within its precinct; the basic genetic materials were sent out to cooperating programs for testing and selection for local use or for crossing with the best local varieties. CIMMYT is concentrating on development of open-pollinated varieties, as contrasted with the inbred hybrids that have been the basis for increased production in the United States and other advanced countries.

Hybrid maize was the miracle crop of the American Midwest in the 1930s, and the U.S. corn-belt states continue to supply nearly half the world's needs, a large proportion of it for livestock feed. Hybrids have been developed in the low-income countries as well, but generally they are not practical for use by the majority of farmers. Hybrid seed production is a job for professionals; the farmer must obtain new seed yearly, and distribution channels must be efficient. Small farmers in the developing countries, who use most of their produce to feed their families and their livestock, have no cash to spend on commercial seed; they set aside a portion of their harvest each year for the next season's planting as their fathers did before them.

Since the new synthetic varieties, when properly handled, can rival the yields of the sophisticated hybrids, even small commercial producers who have a little cash or credit are well advised to spend it on the inputs that help them get the best results—fertilizers, pesticides, weed killers, and the like. CIMMYT maize breeders do not aim to produce finished varieties; they have concentrated on developing pop-
ulations that can either be used di-
rectly in cooperating countries (in
which case they are released by the
national programs and given local
names) or incorporated into local
breeding materials to produce adapted
varieties.

In the early phases of the maize-
breeding program, varieties were de-
developed for high and low altitudes; for
early, intermediate, and late maturity,
so that they could be selected accord-
ing to the length of the growing season
and adjustments could be made for eccen-
tricities of rain or frost; resis-
tance to the diseases prevalent in given
areas was bred into the superior pop-
ulations; and when a high-quality pro-
tein trait was identified, efforts to
incorporate it into tropical varieties
became an important objective. But
although outstanding varieties were
bred, and per-hectare yields in Mexico
showed a 44-percent gain between
1960 and 1967, maize still ran a poor
third in the race to create new super
gains for crash production programs
like those that featured the high-yield-
ing wheat and rice varieties in India,
Pakistan and the Philippines.

However, news from CIMMYT
in the last two or three years adds up
to a major breakthrough in maize that
has gone largely unheralded. Research
aimed at breeding short-statured
plants with wide adaptation, multiple
disease and pest resistance, and high
protein quality, has begun to show
results. This is a radical departure
from past objectives, in that it aims
at developing varieties for use over a
wide area instead of breeding a dis-
tinct maize type for each narrowly
delimited growing environment.

The research techniques used in
this effort are as innovative as the
concept. Populations of as few as 20
or as many as 5,000 plants of similar
aspect but different genetic make-up
are planted together to allow natural
mixing; then the mix is tested under
varying conditions. The plants that
show desirable traits are retained, and
the poorly performing ones are elimi-
nated. In this way a superior popula-
tion is developed, with wide adaptation
and a broad genetic background.

Structural change in the maize
plant has been achieved analogous to
the restructuring of the rice and
wheat plants in the 1960s. By contin-
uous selection of short-statured plants
and by crossing tall tropical plants
with short types, dwarf varieties have
been developed with low ear placement
and upright leaves. The plants' new
features make it possible to increase
population density from 50,000 to
more than 100,000 plants per hectare;
the shorter plants show less tendency
to topple over as the grain ripens, and
they can absorb more fertilizer and
use it to manufacture grain; further-
more, the thicker stands make more
efficient use of solar energy and soil
nutrients, and they compete success-
fully against weeds. Importantly, too,
the higher yields create employment,
since more hands are needed for plant-
ing, harvesting, shelling, hauling, and
handling the increased output. Yields
of such experimental varieties in the
highland tropics have risen from 5-6
tons per hectare to 9-10 tons, and those
in the lowland humid tropics, from
2-3 tons to 5-6 tons.

Another important achievement
is the incorporation of day-length ins-
sensitivity into the short-statured
lines. This was done using the mixed-
population method after preliminary crosses were made between varieties chosen from different latitudes. Wide adaptation to altitude is being sought in much the same manner. Disease and insect resistance is a complicated problem in tropical maize; single-gene resistance has been identified for major diseases, and breeders are now working on multiple resistance, using techniques for deliberate exposure of the plants to the target enemies and selection of resistant plants.

**HIGH-LYSINE MAIZE**

Breeding for high-quality protein in maize is one of the most significant efforts being made in any cereal program. Maize is notably low in protein—it has 9 to 11 percent at the most—and the protein is low in lysine and tryptophan. (A protein source is only as good as its “limiting” amino acid.) About ten years ago, a team of scientists at Purdue University discovered that a mutant gene called opaque-2 modifies the amino acid composition of maize; grain with the opaque-2 trait was soft and dull in appearance, but it had twice as much lysine and tryptophan as ordinary maize. Analytically, this protein was almost as good as that of milk solids; feeding tests with animals and later with malnourished children confirmed the laboratory findings—opaque-2 maize alone was an adequate source of protein for growth and health.

Unfortunately, the recessive opaque-2 gene was not easily transferred to tropical maize, and when this barrier was overcome, other problems arose. Yields of opaque-2 were lower than those of ordinary maize; storage hazards were increased by its higher sugar content; and furthermore, people did not like the look and texture of the kernels. CIMMYT breeders attacked these drawbacks and in 1970 found a way to incorporate the high-lysine trait into a maize with shiny, firm grain. Seed multiplication and a round of international trials began. Populations of high-protein maize with white or yellow grain and with various textures were tested in 15 countries beginning in 1973, and selections are still going on. Breeders believe they can increase total protein content to 10 to 12 percent and retain the high lysine and tryptophan levels.

These little-publicized advances in maize research are capable of leading to a major production breakthrough for tropical regions. Incorporation of the high-lysine trait gives this crop a privileged place in a world where protein malnutrition is becoming a universal concern. The availability of high-yielding, short-statured maize, with high-quality protein, wide...
adaptation, and genetic disease and pest resistance, may prove to be a turning point in rural development programs for maize-producing areas.

The impact that the new maize varieties will have on small-farmer projects is yet to be gauged. CIMMYT's research is continuing to focus on development of open-pollinated varieties suitable for use in rainfed areas, with incorporation of the high-lysine characteristic into types that are locally acceptable. National agricultural agencies in many countries are working on such varieties, and expectations are that within the next few years they will be ready to promote them in national production programs.

Introduction of high-lysine maize into rural development programs is one of the global projects being funded by the United Nations Development Programme. In this effort, CIMMYT is providing research and training as well as consultation and technical assistance to national programs. The confluence of these two important aspects of CIMMYT's maize research may prove to be of the utmost significance, in terms of improved nutrition and increased farm income, for small farmers in maize-growing lands.

WHEAT RESEARCH

The research at CIMMYT that produced the first high-yielding dwarf wheats in the early 1960s and led to their subsequent widely publicized success in Asia, set the stage for even broader experimentation and farther-flung production programs in the 1970s. The widely adapted varieties and their associated technological packages were hailed as a major break-through in agriculture; they enabled Mexico to increase production while decreasing wheat acreage and to export wheat for a period, whereas it had traditionally been a net importer. The new varieties could be transferred to spring-wheat areas at varying latitudes and elevations and were equally at home when planted half-way around the globe. They did better than traditional varieties even under dryland conditions, and under irrigation their yields were spectacular. Backed by strong government campaigns, they brought hopes of food sufficiency to India and Pakistan in the late 1960s. Worldwide these CIMMYT wheats or their derivatives covered about nine thousand hectares in 1956-66; in 1970 they were planted on over 10 million hectares, with India, Pakistan, and Turkey growing the largest acreages. The new varieties got such a good press that the public might have concluded that all major wheat problems were solved.

The men at CIMMYT knew better; they intensified their experimental programs, aiming for greater stability of yield, broader disease and insect resistance, and adaptation to drought, cold, and other stresses. They expanded their training program and lengthened the list of nations receiving assistance or cooperating in research and varietal testing. They entered into a cooperative effort with a number of governments and assistance agencies in the Near and Middle East to monitor wheat diseases and to try to prevent epidemics. They undertook cooperative research with U.S. universities and the Government of Turkey aimed at developing winter wheats; triticale research in coopera-
CIMMYT helps develop strategies for small farmers.

tion with the University of Manitoba was accelerated; and studies on protein levels in wheat were launched in cooperation with the University of Nebraska.

CIMMYT scientists are well aware that in order to fill the world's bare cupboards and empty bread baskets, high-yielding wheats must be bred and farming practices developed for a great many different environments—not only areas previously neglected by science, but those where changing climates and soil conditions create a whole new set of problems, or where new diseases and pests invade overnight or old plant enemies suddenly appear in new and lethal mutations. Wheat improvement, whether on the experiment station or in the wheat-growing world, is an open-ended pursuit. And systematic promotion of improved wheat technology in the many countries where it has not yet penetrated is still a virtually untapped resource for increasing world supplies.

Current top-priority aims of wheat research are to stabilize disease resistance, to spread the use of improved seed and agronomic practices, to raise protein and lysine levels, and to find sources of drought tolerance. A primary factor in yield stability is resistance to diseases and insects; breeders are using innovative techniques that include selection of the best lines of resistant material over several growing cycles, inoculation with various pathogens or deliberate exposure to insects, and testing under a wide variety of environments, first in Mexico and then in the international nurseries program. The continual addition of new genetic material has succeeded in developing a series of new wheat varieties resistant to rusts; attention is being focused on Septoria leaf spot, mildew, and scab. Sources of resistance are being incorporated into the breeding program, and some resistant lines have emerged.

Crosses of spring and winter wheat are being made in the expectation of improving the root system of the spring bread wheats so that they will be more tolerant of drought; the breeders also hope the crosses will result in transfer of cold tolerance and disease and pest resistance to the spring wheats. In the same operation they are aiming to transfer traits such as dwarf stature, responsiveness to fertilizer, and disease resistance to the winter wheat lines. Early tests of spring-winter crosses show promising results.

A program to improve durum
wheat has been under way since 1968. Durums are used for a wide variety of macaroni-type products and for Arab couscous, which are important in the Mediterranean area and the Middle East. Durum wheat is also raised in India, the United States, Canada, Argentina, Chile, and the USSR. High-yielding, fertilizer-responsive dwarf lines of durum have been bred, and genes for resistance to major diseases have been identified. CIMMYT’s milling and baking laboratory is testing the lines for industrial quality, and breeders have sent out nurseries to be grown in over 30 countries. One of CIMMYT’s superior lines showed record yields in Turkey and was released as a commercial variety.

TRITICALE AND BARLEY

Triticale, a cross between wheat and rye, is being improved along the same lines as wheat: genes for dwarfing have been introduced, and the shorter plants can absorb more nitrogen and yield up to six or seven tons per hectare. The drawback of shrivelled grain is being overcome, and triticale is already being grown commercially for food in Eastern Europe, for forage in the U.S., and for distilling whiskey in Canada. It has better tolerance of cold and drought than wheat has, and some experimental lines show higher protein and lysine levels than either of the parent species.

Barley is eaten by some 200 million people, but most research has been focused on the hulled types that are used for animal feed and for brewing. Now CIMMYT is using the same techniques applied to wheat for improving the kinds of barley that are used for human food. Sources have been found for breeding in high protein and lysine levels as well as good agronomic characteristics. Four lines were found having over 20 percent protein—about double that of wheat and almost as high as the protein in grain legumes. Superior varieties will be important as both food and animal feed in areas of North Africa, the Near East, the Himalayas, the Andes, and Eastern Europe, wherever low rainfall, high elevations, cool temperatures, and short growing seasons make wheat raising hazardous.

As a general principle, CIMMYT scientists believe in developing alternate cereals like barley and triticale for areas that are marginal for wheat, and sorghum for lands where maize is vulnerable. Barley and sorghum have many of the same uses as the grains they replace, and offer the grower the highly valued advantage of greater security.

NEW DIRECTIONS

In addition to improvement of these crops, breeders are experimenting with wide crosses on the order of the wheat-rye cross that produced triticale. Such research might be long in producing concrete results, but the chance of creating hardier and more prolific food grains for future generations cannot be overlooked. For example, some preliminary work with maize, sorghum, and Tripsacum—a wild relative of maize—seems to hold promise. CIMMYT is growing a Tripsacum garden to multiply the genetic resources available to breeders. Other crosses that are receiving considera-
tion include wheat and barley, wheat and oats, and wheat and wild grasses. CIMMYT will encourage universities and other basic research centers to probe further into the possibilities of wide crosses and other “radical” research it considers promising.

In this, as in its major programs, CIMMYT's role as an international clearing-house for exchange of scientific information and airing of vital agricultural questions will prove useful. CIMMYT's technical publications in Spanish, English, and French are circulated to wheat and maize scientists; its conferences and symposia bring experts from the four corners of the earth together to talk wheat and maize—or national production planning, agricultural education, world food-population balance, and other topics that exercise the best minds in the field. Through many channels—cooperative research; the training program and alumni network; consultation services; resident overseas staff; official contacts with governments, universities, donor agencies, other international institutes, and regional and national programs; as well as professional ties of its staff members with other scientists—CIMMYT has a finger on the pulse of world agriculture.
The International Institute of Tropical Agriculture (IITA) was formed in 1967 through an agreement with the Government of Nigeria, which provided about 1,000 hectares of land near the University of Ibadan, one of Africa's finest modern centers of learning. Improvement of the quality and quantity of the major food crops of the lowland humid tropics is IITA's stated objective, but this broad purpose has been sharpened in conformity with the principle of focusing intensive interdisciplinary research on a limited range of projects. A fairly large number of crops is important in this agroclimatic zone, and each one could doubtless contribute more to food supplies if given the benefit of modern research and production technology.

The popular vision of the tropics as a perpetual garden of green growing things, with plants always in flower and fruit, ripening in the equatorial sunshine and freshened by abundant rains, forms a grim contrast with present-day actuality. The fact is that the countries in the humid tropics are finding it harder and harder to grow enough food for their people. But there is enough truth behind the fiction of the bountiful tropical paradise to stir the imagination and challenge the highest efforts of modern scientific agriculture. The food-producing potential of these lands is unknown—some estimate it to be very great. There is no doubt that they could produce substantially more than they do, provided research were focused on their outstanding problems and the proper inputs made available. The solar energy and heavy rainfalls are not the unalloyed assets they would appear to be; to turn them to good account, a number of obstacles must be overcome, first among which is the difficulty of handling tropical soils and maintaining their fertility under regimes of sustaining cropping.

The way small rural communities have managed the soils in the past has been to use them for a period of one to three years, then abandon them to wild vegetation and let nature restore them—the time-honored practice of shifting cultivation with its long intervals of “bush fallow.” In the days when land was plentiful, the fallow period could last up to 20 years or more. This regime is prodigal with land and labor—sometimes as many as 15 hectares are needed to feed one person, and every few years a new era of thick jungle growth has to be cleared, mainly by hand, before crops can be planted. The land is never fully
cleared, since the larger trees are generally left standing. The system sustained life for centuries under the hostile conditions of the tropics, but it also absorbed most of the energies of the people who practiced it.

In recent times, however, rising populations have forced rural communities to put idled land back into use before the wild growth has had time to restore the soil to its primal strength. Under continuous cropping, the abundant sunshine and rainfall soon become a liability, tending to aggravate soil erosion, leaching, and nutrient depletion. The result has been deterioration of the soils, decreased crop yields, and lower-quality and scarcer food supplies.

Since the Second World War, the agricultural situation has progressively worsened, adding its toll to the mounting political, social, and economic burdens the African nations have had to face. Efforts have been undertaken to improve existing knowledge about growing conditions for food crops as well as for commercial and export crops in various parts of the humid tropics, and progress has been made in a number of areas. Soon after its establishment, IITA began to form cooperative ties with many of the existing programs, so as eventually to develop collaborative crop research and testing mechanisms and to take advantage of the experience gained by others who have worked with the different soils and climatic conditions in the humid tropics. Extension training efforts are also planned in cooperation with public and private organizations in various African countries as IITA's research programs develop improved crop varieties as well as farming methods.

IITA is concentrating its efforts in four central research programs. Three are crop-centered, dealing with improvement of cereal grains, grain legumes, and roots and tubers; the fourth is focused on farming systems. The materials and methods developed in the crop programs are used in the farming-systems research to help define the most advantageous use of available resources, and results are in turn fed back to the crop programs to serve as a guide in the development of improved varieties and agronomic practices. The small farmer's needs are considered paramount; the coordinated research of all four major programs is aimed at developing crop combinations and rotations and farm management systems that are within his economic and ecological compass.

Soils are the keystone of the farming-systems research. The challenge to modern science is to find methods that work as well as the system evolved by early Iron Age man, which has been used successfully down to our own generation by small rural communities dependent on subsistence farming. If the practice of shifting cultivation is to be superseded—and pressures on land and food supplies rule that it must be—new means have to be found to conserve moisture, restore organic matter and preserve soil fertility, prevent erosion and leaching, control weeds, keep down insect and nematode populations (all of which the bush fallow achieves), and in addition support continuous cropping and produce higher per-unit yields.

Better-quality diets also figure on IITA's priority list; for this reason emphasis is being placed on the food
legumes, especially cowpeas, which are high in protein, on high-lysine maize, and on rice with better-quality protein. Calorie needs are important, too; the root and tuber program is aiming for higher yields per hectare and higher carbohydrate content in cassava, sweet potato, and yam—all excellent energy sources.

IITA's long-range mission is being tackled by a dynamic leadership and professional staff. The Institute seems to thrive on challenge; its accomplishments in the areas in which it has concentrated its energies are considerable—in the judgment of experts in the field, some have the valences of breakthroughs.

Highlights from the research programs include the discovery that slight variations in soil temperature determine whether or not maize seed will germinate and whether seedlings will survive; and the development of locally adapted varieties of high-lysine maize. Tillage and mulching techniques have been designed that materially affect soil moisture, temperature, and topsoil retention. New varieties coming out of the legumes program have the potential of producing one-third more under controlled conditions than the best varieties tested, and they could probably give eight times the average yield achieved in farmers' fields. Progress made in the root and tuber program has made possible genetic improvement of yams through crossbreeding—a difficult and rare accomplishment.

**FARMING SYSTEMS**

In order to reverse the downward trend in food production, a fundamental change has to be made in African agricultural systems in the humid tropics. It involves not only the use of high-yielding, adapted crop varieties and the accompanying package of improved practices, but in some cases an assault on the farmers' concepts of land use and possibly of proprietorship—a modification not only of their patterns of cultivation but of their way of life.

For the present, IITA's interdisciplinary teams are working chiefly on the technological aspects of farming practices for continuous cropping. One precept that has been repeatedly validated by experience with agricultural development programs is that in making recommendations which involve radical changes in working habits or folkways, one must be certain the new practices will bring palpable benefits.

Soils are receiving thorough study from the point of view of structure, fertility, chemistry, and physics, and some remarkable facts have come to light. A study of soil profiles in Nigeria and neighboring countries has identified alluvial soils with high productive potential for year-round cropping. IITA scientists estimate that West Africa has millions of hectares that could be turned into productive farmlands at relatively low cost.

Soil management for maize growing has been studied, and simple, economical methods have been worked out, including fertilization, proper plant population, weed control, and protection against insect invasions, with a view to maintaining high yields under continuous cropping. On the farm, these practices could give good maize yields from the same land over several years, in the opinion of IITA's
scientists. (However, whether experimental-farm technology, however simple and practical, can be efficiently moved out into the growers’ fields is still in the realm of conjecture at IITA, and methods and approaches are being thoughtfully deliberated before any predictions are made.)

Weed control research for different crops has identified the most effective chemicals for use with root and tuber crops, rice, and cowpeas. Weed competition studies yielded data on optimal timing of weeding, or use of contact herbicides, for highest crop yields.

Mulching and minimum tillage, in combination with weed control measures, have been found to have several advantages, including keeping topsoil in place, holding moisture reserves in the upper layer of cropped soils, and lowering soil temperature. Marked benefits were recorded in both yam and maize crops.

Leaving crop residues on the ground after harvest, or treating wild vegetation with contact herbicides and sowing the new crop through the layer of felled weeds, are variations of the same approach. Like mulching and zero tillage, they mimic the bush fallow system, and are, of course, a good deal handier. This tactic has given good results with maize, but problems arise with small-seeded plants like rice, whose shoots are too fragile to penetrate a thick layer of plant residues.

CEREAL IMPROVEMENT

Over the past 25 years, continually expanding rice and maize acreage has compensated for consistently low yields. IITA works in close cooperation with IRRI and CIMMYT, which, respectively, have major responsibility for rice and maize—the major cereals grown in the humid tropics.

IRRI rice varieties can be used directly for irrigated fields in this region, so IITA has concentrated on developing rice for upland farms, which account for about 80 percent of the crop grown in West Africa. Using IRRI breeding materials in combination with local rices, IITA scientists have developed locally adapted varieties, and promising lines are now being tested in different ecological zones. The West Africa Rice Development Association (WARDA), an organization sponsored by 13 African governments, is cooperating in these regional trials.

For the upland areas where drought is a problem, IITA is seeking early-maturing types with high-yield potential; two varieties have been identified which yield more than 4,000 kilograms per hectare and have a growing cycle of 100 to 107 days. African varieties with resistance to local races of rice blast and tolerance to drought have been combined with materials that have the IRRI plant type, and the progeny are being tested at IITA and regionally through WARDA. Minikits developed at IITA for upland rice production are also being tested through the Nigerian Accelerated Food Production Program. IITA has helped train rice extension workers for WARDA and for the Nigerian food program at both professional and pre-professional levels.

High-yielding maize composites based on CIMMYT materials are being tested at IITA and show prom-
Scientists are developing high-yielding rice varieties. The past year has shown promising results. Two years of breeding at IITA, three generations can be grown in a year, taking advantage of the two rainy seasons in Nigeria. Early trials during the dry season have resulted in yield improvements of 50 percent, as well as higher protein content. Nigerian composites having the opaque-2 gene have been developed, and some of the lines have hard-borne material.

The effect of high soil temperature on maize germination and early growth has been pointed out, and some progress has been made toward identifying maize that tolerates higher temperatures. There is some evidence that inheritance of this trait may be relatively simple, opening up the possibility that maize growing may be extended to hotter climates.

Sources of genetic resistance to stem-borers of rice are being sought in wild rice as well as in IRRRI’s IR-36. Some resistance to maize stem-borers has been found. IITA populations are being raised by IITA’s entomologists for use in screening plant materials for their reaction to pests and larvae.

4 GRAIN LEGUMES

IITA has major world responsibility for cowpea improvement, since that is the legume crop most widely grown in Africa can be improved. Of the 8 million bushels of cowpea grown worldwide, over 1 million are grown in Africa. Research is also progressing on lima bean, African yam bean, and several other food legumes that are important in this type of environment or that can be adapted to fitting of cropping patterns. Work on cowpea, beans, and red, and groundnut varieties is being continued on a research basis, since both crops have considerable potential for the African economies as food crops. Groundnut varieties can also be grown in wetter environments as a cash crop to increase production and animal feed.

IITA’s germplasm collection of food legumes numbers between 13,000 and 7,000 entries; over 4,000 varieties of cowpea, 3,500 of pigeon peas, 600 of soybeans, and 200 of lima beans have been assessed, in addition to numerous examples of other pulses. A systematic collection effort is being undertaken in western and central Africa, with the aim of assembling all the available genetic diversity in a number of indigenous legume species.

Cowpea is the legume receiving priority research attention because it contains high protein levels, with the highest percentage of methionine of all the food legumes. It is a versatile

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crop, growing in some areas during the rainy season, in others on residual moisture at the end of the rains, and in some areas as an irrigated crop. Cowpeas are eaten as green pods, dried beans, and sprouted seedlings; crop residues are fed to livestock. Productivity should be susceptible to considerable improvement, since average yields are now about 370 kilograms per hectare in Africa, whereas IITA has achieved yields six times as high. Institute scientists estimate that production worldwide could be increased by at least a million tons a year.

The cowpea breeding program has developed improved varieties which are being sent out in uniform trials to cooperating stations around the world. A team made up of plant breeder, physiologist, agronomist, entomologist, plant pathologist, and biochemist is aiming to develop a cowpea plant type suited for the humid tropical growing environment, with high yielding ability, good grain quality, optimal performance in cropping combinations, and resistance to diseases and insects. Genetic sources have been found for erect growth, prolific podding, neutrality to day length, and resistance to several major diseases, as well as for tolerance or resistance to thrips and other pests. Some improved varieties are ready for testing on farms. The grain legume team is also studying plant density, spacing, fertility levels, soil conditions, and time of harvest as they affect plant development and productivity.

Progress has been made with pigeon peas, lima beans, and jack beans; the research holds promise for increased yields, improved resistance to drought, and freedom from serious diseases and pests. The work on pigeon peas will be coordinated with the program at ICRISAT, which has major responsibility for this crop in the international-institute network.

ROOT AND TUBER CROPS

Starchy roots and tubers, chiefly cassava, sweet potato, and yam, are the major energy foods of the African humid tropics. About 50 million tons of these crops are grown annually, including 30 million of cassava. IITA's aim is to improve yields, adaptation, and food quality in the three crops and to overcome specific restraints to production in each one.

In cassava, the main problem is disease. Cassava mosaic and bacterial blight can substantially reduce yields; in Zaire and Nigeria bacterial blight has been known to cause crop losses of up to 60 percent. Sources of resistance to mosaic have been found in material acquired from Nigerian breeders; over a hundred thousand crosses have been made, and several hundred plants with resistance to the disease have been grown.

A new breeding technique is being used, based on natural cross-pollination in populations containing a wide diversity of genetic materials. Large numbers of recombinations are evaluated, and selections are made for vegetative propagation.

Another goal of the cassava work is to produce varieties that have a low level of cyanide. A rapid screening test has been devised, and a number of low-cyanide lines have been found.

Sweet potato research has produced high-yielding clones which can give 40 tons per hectare in the rainy
season and over 30 tons in the dry, in each case within four months time. The chief constraint in this crop is the sweet potato weevil, and after screening thousands of lines, a few with resistance to weevils have been found. Breeders are also trying to lower the sugar content of sweet potato varieties that originated in Asia or South America, to make them more like the types preferred by Africans. Improved varieties are ready for field testing, and IITA is working through the extension networks of various private and governmental organizations to get the crop planted by Nigerian farmers. IITA is also trying to develop better storage methods and to breed sweet potato varieties that keep well.

A tissue culture program has been started as a step toward producing disease-free vegetative breeding materials that can cross national and continental boundaries without running up against plant quarantine restrictions. Using this technique, extensive distribution of cassava and sweet potato materials to national breeding programs is planned for the future.

Yams (Dioscorea spp) grown in the humid tropics do not lend themselves easily to genetic improvement, because they rarely flower or set seed. However, the IITA breeding team has managed to grow 600 seedlings, which will make hybridization possible. A collection of genetic materials is under way at the Institute, starting with African varieties. Material from Southeast Asia and the West Indies will also be acquired, but with difficulty because of the restrictions on importation of vegetative plants.

OUTREACH

IITA's presence as a center of excellence is beginning to benefit the countries within the area of its mandate; in addition to cementing cooperative relationships with a number of countries in preparation for long-range programs, IITA has received requests for consultation and assistance with urgent local problems. A recent instance was the success of a team of IITA scientists who went to Zaire at the request of the Government to identify the cause of the devastating "candle disease" of cassava and to find means of controlling it. This is an outstanding example of how top-flight scientific resources can be brought in to deal with an immediate, crucial problem. IITA feels, however, that it best serves the countries of the humid tropical zone by long-range planning for research and production programs, and that emergency efforts should not become an excessive drain on its resources.

With support from a number of donor agencies, IITA is undertaking cooperative programs and consultation with several nations at the request of their governments. It is working with CIMMYT in Zaire's national maize program, and it has been cooperating in the Nigerian Government's Accelerated Food Production Program, along with scientists from IRRI and CIMMYT. Similarly, it is offering consultative services on maize and grain legumes in Tanzania, with the cooperation of CIMMYT. IITA personnel are now posted in Liberia and Sierra Leone to assist with rice cultivation. Ghana has also made contact with the Institute for cooperative
research on soil conservation and ero-
sion control.

In addition to these activities, IITA holds conferences which bring specialists to Ibadan for short seminars on topics of concern to workers in tropical agriculture. Past conferences have dealt with soils, irrigation, cassava mosaic, grain legumes, and root crops.

A Communications and Information Unit prepares and disseminates reports on IITA’s programs and research to interested organizations, government agencies, and individual scientists. Publications in both French and English will serve the two major language groups in the African tropical zone.

The Library and Documentation Service is acquiring current publications related to IITA’s major research activities. Annotated bibliographies are being prepared of the research literature pertinent to tropical agriculture; a retrieval service is being organized so that the publications listed in the bibliographies can be made available to scientists in other countries.

TRAINING

Resident training programs in tropical agriculture are operated at several levels. Research training is offered for candidates from developed and developing countries who will eventually assume responsibility for national and regional production research programs in the tropics. The training includes one to two years of instruction and field experience; candidates submit written reports, present their findings at seminars, and prepare papers for publication. Their projects are integrated with IITA’s ongoing research, and some of the trainees have already made valuable contributions to its work. Emphasis is placed on production-oriented thinking and techniques, since many of the participants come to IITA with academic training but little field experience.

IITA also offers opportunities for higher-degree candidates from universities in Africa, Europe, and North America who want to conduct their thesis research in a tropical environment. The Institute already has cooperative relationships with eight institutions, and plans to enter into similar arrangements with others. IITA also accommodates a few post-doctoral scientists who are doing research relevant to the Institute’s program.

Production training programs,
which may last from three months to a year, are offered to give practical experience to trainers and supervisors who will in turn teach extension agents in their home countries. They learn how to handle a given crop and how to run an accelerated production campaign. The program of training in rice production, in particular, is expanding and ultimately may be able to handle as many as a hundred participants.

IITA is an added dimension in the efforts of the African nations to improve the agricultural outlook for the people of the lowland humid tropics. It can concentrate intensive research on a limited number of key problems, while national and regional programs necessarily cover a broader field. The two approaches complement each other, and their interaction should benefit the farmer and the consumer. Reciprocity is a basic theme in IITA’s thinking and action: its leaders expect the Institute to act as a catalyst in effecting changes in technology and promoting agricultural development; they emphasize that it can succeed in its objectives only by working hand in hand with existing organizations.
The International Center of Tropical Agriculture (CIAT) represents a departure from the crop-centered approach to agricultural improvement typified by CIMMYT and IRRI. Its primary focus is on a region—the lowland tropics of the Western Hemisphere—and within that framework on the key factors that influence the development of a productive farm sector under given agroclimatic and socioeconomic conditions. Some of CIAT's programs are commodity centered, while others deal with farming systems and the development of prototype units for crop or livestock raising or for mixed farming, with emphasis on the small family farm. CIAT's concern with extension and outreach is cardinal; from the start the Center was conceived as a hub for stimulating the work of national and regional agricultural efforts and working through them to disseminate research findings and technological improvements.

The tropics of Latin America are marked by sharp contrasts and endless variations. The high-elevation savannahs with good farmland and favorable climate, the harsh Andean slopes, the infertile lowland plains with alternating droughts and floods, the rich river valleys and marshy deltas, the impenetrable rainforests—all have such distinctive features, arising from both natural endowment and human intervention, that a program aspiring to benefit agricultural production and foster rural welfare must proceed in several directions. And it must pioneer, as little in the way of scientific exploration has prepared the way.

CIAT's geographical province lies below the well-favored highland plateaus; it includes undeveloped lands of fair to good potential, where agriculturists believe modern technology can effect substantial change, as well as jungle and desert areas, where agricultural development is a long-range but challenging possibility for the future.

Yields are low in every major crop, except for the few export commodities, such as cotton, coffee and sugar, that have received attention and investment because of their hard-currency value in world markets. Maize, rice, cassava, and beans—the foods that sustain the people—generally make a poor showing; beef cattle and swine bring low returns except on modern commercial ranches. Small landholdings account for the great bulk of food and feed production, and much of it is for home consumption. In this milieu, farming is geared at the
lowest level of investment, innovation, and risk—not because farmers are illiterate or backward or slow to sense the winds of change, but because in their experience of the hazards and caprices of nature and the marketplace, that is the most practical way to insure survival from one year to the next. And survival even at subsistence level in a rural population that is growing at an annual rate of about 3 percent requires diligence, and each year becomes more problematic.

Such considerations have shaped CIAT's major programs. Agricultural research projects in the Latin American tropics must be at once discrete and interlocked: there is no single obstacle or constellation of constraints whose removal would assure progress. For example, animal diseases, animal nutrition, and livestock management must be investigated separately by specialists, but unless livestock raising is economical for the small producer and fits into a workable pattern which permits him to obtain the necessary supplies and services and to sell his products at a fair profit, the vast majority of growers will not benefit from the scientists' work. The same holds true in crop production; no single crop dominates throughout the region—cassava may be the major food in one area, maize in another, and rice in a third; beans are common as a protein source.

Genetic improvement and agronomic practices developed for beans and maize have to be meshed with the development of methods that take into account the prevailing practice of planting these two crops together, the maize stalks serving as bean-poles and the bean plants enriching the soil with their nitrogen-trapping mechanism. Soil research or breeding of tropical forage legumes and grasses, the search for adapted food-crop species for the leached-out soils of the Llanos (the plains of eastern Colombia and western Venezuela), or work on drainage and flood control for the coastal plains, has to be done with some knowledge of the type of farm family that will choose to settle in these desolate areas, and what their needs will be in terms of access to inputs, services, and markets as well as food and shelter. In fact, CIAT leaders believe that the multidisciplinary, integrated research program on small-farm units may turn out to be one of the Center's most important contributions to agricultural development in much of Central and South America.

CIAT has four food-crop programs: cassava and field beans (*Phaseolus vulgaris*), for which it has assumed major responsibility in the international-institute network; and rice and maize, for which it has charge on a local basis, with backstopping from IRRI and CIMMYT.

Livestock programs deal with beef cattle, a major CIAT thrust, and with swine, a more modest program.

**CASSAVA**

The starchy root cassava, or yuca, is a favorite with the people of Latin America and the Caribbean, who cook and use it in dozens of ways. It is also a staple food in many parts of Africa and South Asia. Although low in protein, it is a good energy supplier. Dried or fresh cassava can be used as the carbohydrate fraction in animal rations. Three-month-old
leaves contain between 21 and 30 percent protein, on a dry-weight basis, and are being used at CIAT in swine feeding experiments. Cassava is also grown in Africa and parts of Asia, where it was introduced from the Western Hemisphere, but yields are generally low (7.7 tons per hectare in Africa, 9.5 in Asia, 14 in Latin America). Experimental trials suggest that yields could be raised to 50 tons per hectare by selecting for high productivity and disease resistance and using good agronomic practices.

CIAT is working on simple storage techniques for fresh roots as well as on drying methods for longer keeping. It is also screening its germ plasm collection of 2,000 accessions for “sweet” strains that are low in cyanide—one of the drawbacks of “bitter” cassava being that it can release enough of the poison to result in goiter and other health problems.

Breeders are seeking cassava with higher protein levels, higher yields, and varietal resistance to diseases. Control of insect pests and weeds is being sought through genetic and chemical means, with a view to their cost and feasibility in the small-farm context. Economists are studying potential markets and outlets for large-scale production, such as animal feed, partial substitution for wheat flour in bread, and uses as industrial starch.

Starchy roots—chiefly cassava—were among the few commodities that exceeded the growth targets set for the 1960s by the FAO's Provisional Indicative World Plan for Agricultural Development, and its potential as both a food and export crop for tropical countries is of capital importance. CIAT has assembled most of the world’s literature on this crop and has developed an information retrieval system capable of furnishing scientists with material on specific aspects of research.

FIELD BEANS

CIAT assumed responsibility for field beans in Latin America and the Caribbean in 1972. In this region an adequate supply of beans means the difference between malnutrition and health for large numbers of rural people deprived of animal protein.

Bean yields in the tropics (around 600 kilograms per hectare) are low compared with average yields of 1,460 kilos in the U.S. and nearly 1,600 in Canada. In the tropics, the crop is afflicted by many more diseases than in the temperate zone, and its nitrogen-fixation capacity has not been exploited.

CIAT has assembled a germ plasm collection of about 10,180 ac-
cessions, and sources of an estimated 5,000 more are known. Screening for 23 characteristics has been carried out at the Center (at 1,000 meters above sea level) and is now being repeated in three other ecological zones. Breeders seek traits that will bring higher yields through alteration of plant structure and physiology, resistance to diseases and insects, and the ability to adapt to the hot tropics. The program aims at developing basic populations for different elevations and distributing them to cooperating national bean breeding programs for further adaptation.

The search for effective inoculants of *Rhizobium*, the bacteria that control the nitrogen-fixing system of the bean roots, is based on testing of CIAT's collection of 400 *Rhizobium* strains against the best bean varieties; yields have almost doubled in some of the tests. CIAT's bean team is producing inoculant strains that can survive storage and transport in the tropics and is also studying ways of overcoming the adverse effects of acid soils on seed inoculation. Resistance to major insects has been identified, and work on horizontal, or wide-spectrum resistance to diseases is going forward. Economic factors limiting bean production and consumption are also being studied. Plans are being shaped for a cooperative regional network, based on CIAT, to promote and coordinate work on field bean improvement.

**MAIZE**

The CIAT maize program coordinates its effort with CIMMYT's international maize improvement work and has participated in adapting and testing the new short plant lines from CIMMYT's breeding program. Research has been aimed at development of locally adapted varieties of short-statured, high-lysine maize with wide adaptation to variations in day length and temperature, as well as high yield, broad disease and pest resistance, and consumer acceptability. The sturdy dwarf plants are especially practical for the bean-maize association used by many small farmers in CIAT's zone of activity, and in combination with new lines having high-quality protein and hard kernels, they are expected to increase the use of this type of maize by local consumers. CIAT's maize and soils teams are testing various land-preparation and planting systems for the crop under local conditions and are trying to identify maize varieties, as well as maize and bean combinations, that will do well in the acid soils of the Llanos.

**RICE**

Improved rices for the Latin American tropics have been developed by CIAT from high-yielding dwarf lines, and a number of locally adapted varieties supplied by CIAT and IRRI have been released by national programs under various names. Latin America produced over seven million metric tons of milled rice in 1970, which was 127,000 tons less than it consumed; a smaller deficit is projected for 1980, in spite of growing population; demand is expected to top the projected production of 9.6 million tons by only 75,000 tons. FAO figures for the decade 1961-71 show a growth rate for rice production of 3.4 percent per year; the target rate for 1975-85
has been set at 3.3 percent annually.

Both rice acreage and per-unit yields have increased in various areas of Latin America and the Caribbean, and CIAT is continuing to promote development of improved agronomic practices and use of the high-yielding varieties. Rice blast has been a serious problem with all commercial varieties, and CIAT breeders are working on incorporation of genes from local varieties that carry generalized blast resistance.

Optimal rates and timing of fertilizer application, ratooning (the ability to grow a second crop from the crown and root system of the first), and water management are under study in CIAT’s agronomic program. Research has been started on improved upland rice and development of cultivation practices for the poor-quality, acid soils of the Llanos. Upland rice accounts for 70 percent of the rice crop in Central and South America, and this aspect of the program is expected to receive more emphasis.

**BEF CATTLE**

The Llanos of Colombia, Venezuela, and Ecuador; the Campo Cerrado of Brazil; and similar areas in Bolivia and Paraguay embrace vast tracts of under-utilized grassland and scrub timber, estimated at 300 million hectares; these lands are largely unsuitable for cropping, but with proper management might support a profitable beef cattle industry. Beef production, however, in this area as well as in other tropical environments of Latin America, has a long way to go to fulfill its potential. Calving rates are low—about 40 to 50 percent, as compared with 85 to 90 percent in North America—and animals take up to five years to reach market weight. Poor nutrition, poor health, and poor management all contribute to the stagnation of an industry that accounts for half of the 250 million cattle in Latin America. Each of these drawbacks has known correctives which could be applied if adequate investment were made in supportive services and extension, but each also has important unknowns that only applied research will remedy.

CIAT’s program concentrates on providing adequate feed supply through improved pastures and supplementation, control of disease and parasitism, and development of beef production systems, the latter chiefly for the family-size unit. The Center is working closely with the Colombian Institute of Agriculture (ICA), with 60 percent of its work located at two of ICA’s experimental stations in cattle-raising country—one in the Llanos and one in the North Coast lowlands. Research activities at CIAT include screening and breeding of tropical pasture legumes and native grasses for use on highly acid, mineral-deficient soils; establishment of improved pastures; mineral and protein supplementation; and work on animal health, especially as it affects reproductive performance. Major attention is also given to hemoparasitic diseases. Training for specialists in various aspects of livestock production and research is built into the program.

One key project involves observation of nine beef herds over an extended period, to determine the effects on productivity of different pasture types, mineral and protein supplemen-
tation, herd management, and related factors. A similar study concentrating on the effects of various pasture systems is projected. Economic analysis of the data will contribute to development of practical husbandry techniques and beef production systems.

SWINE

One hundred million swine are found in the lowland tropics, up to 90 percent of them on subsistence farms. Poor nutrition and management as well as substandard sanitation are the main barriers to efficient production. The small farmer's take from his herd is only a seventh or an eighth of what is usual in commercial operations in developed countries. In CIAT's swine program, identification of cheap local sources of both energy and protein and improved management practices that are feasible on the small farm go hand in hand with development of extension and demonstration at the village level.

Work on various nutrient sources is providing a broad basis of knowledge for swine improvement in different regions where the available feed sources vary widely. Research projects are also under way on the major swine diseases and on development of optimal management techniques at low cost. The training program for production specialists for the low and tropics has included scientists from Colombia, Ecuador, Peru, Costa Rica, Paraguay, and Bolivia, and with the trained scientists outreach projects are now being developed in all of these countries.

SMALL-FARM SYSTEMS

Cutting across the lines of the crop and livestock programs, CIAT's small farm systems team is working on the analysis of small-farm dynamics and the factors that influence the farmer's decisions in the context of agricultural institutions and economic policy at the national level. Interaction with the researchers engaged in the various commodity programs works in two ways: the systems team is developing information that can be helpful in the extension of new technologies to the producers of the major crops and animal species under investigation and the commodity programs are providing improved production inputs and management techniques, furnish the systems team with the indispensable biological and material components of improvement of farm income and family nutrition.

Feedback from data dealing with
the reasons for adoption or rejection of new technologies as well as identification of gaps in available knowledge provides guidelines for determining CIAT's own program priorities. The small-farming systems work also aims at defining methods of analysis and evaluation that ultimately can be used by national programs in Latin American countries for introducing technological improvements and monitoring their effects on the rural sector.

TRAINING

CIAT's training program is fundamental to the concept of the Center as a nucleus of research and information, extending its influence through cooperative programs with national organizations in the Latin American tropics. CIAT has built up this level of activity to include some 200 trainees a year. Twelve-month courses for production specialists are divided between field work and academic work; postgraduate in-service trainees from various agricultural agencies, advanced-degree candidates conducting research projects, and special trainees in various fields are also in residence for varying periods of time. CIAT's alumni are vital links in a growing network of professionals dedicated to accelerating agricultural growth and change in their own countries.

The Center views "training trainers" in integrated research-and-production methods as one of its most important functions, since a practical orientation is largely foreign to traditional agricultural science education in Latin America. Recently, CIAT leaders have had some success in encouraging national universities to introduce field experience into their undergraduate curricula, although educators schooled in this approach are still in short supply.

OUTREACH

Direct consultation with governments and agricultural agencies that request help from CIAT's scientific staff has also been an important activity from the start. Notably, Ecuador's beef cattle and swine production projects have been backstopped by CIAT in both research and training, and an agricultural developmental effort being organized in Guatemala is currently receiving help from CIAT staff.

Seminars, workshops, and professional conferences figure importantly on CIAT's calendar. Around the year professional groups meet in the conference rooms and amphitheatre to thrash out problems of national and international production and research, arrange for scientific exchanges, define priorities, eliminate overlapping efforts, and generally sharpen the focus of expert opinion on the barriers to agricultural advance.

Communication, in the largest sense of the word, is a goal that CIAT's leaders and staff work hard at; designed as an international meeting-ground for men and women of influence in the sciences, education, and public affairs from all over the Americas, the Center fills a quasi-diplomatic role that is essential for agricultural and economic progress in the area of its mandate, and, indeed, to understanding and cooperation on related issues throughout the hemisphere.
The dryland farmer of the world’s semi-arid tropics tackles a stern environment with limited resources and long odds against him.

His soils are old and worn. He seldom has enough fertilizer. His seed varieties have come down from ages of selection for ability to produce some yield in the worst of times—the defense against starvation; such varieties don’t produce truly high yields in the best of times. His power is usually human or animal, and both are subject to the poor, plodding performance of the undernourished.

But most limited is the resource water: limited in amount and limited in distribution in these lands of a short rainy season and a longer dry season.

A major part of the food supply of some 400 million persons rests on the success of the dryland farmer of the semi-arid tropics. These persons are found in parts of Australia and South-east Asia, India, the Middle East, two wide belts in Africa, areas of South America, and much of Mexico.

It is true that “miracle varieties” and new packages of technology have boosted food supplies to a limited extent here as in other parts of the developing world. The increases have come mainly where irrigation can be part of the package.

The need for increased output by the dryland farmer, who is dependent upon the rain which falls on his land, continues unabated. One reason is simply larger populations. Another reason is the worsening situation of protein nutrition: the Green Revolution brought more cereals. Those cereals—and more are still needed—are short in some of the essential amino acids which compose protein. Improved nutrition for the people demands more livestock protein and, especially in resource-poor countries, more grain legumes to balance the added cereals. “Re-designed” cereals with upgraded nutrition for the people demands more livestock protein and, especially in resource-poor countries, more grain legumes to balance the added cereals.

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farmer which can substantially improve the size and dependability of his harvests.

In mobilizing high-level scientific resources for an all-out effort to improve the productivity of arid lands and the potential of dryland crops, ICRISAT's leaders are determined to keep the Institute's sights fixed on the small cultivator of humble means. They are developing technology that will make sense to him in his world hedged in by poverty and fear of risk. But at the same time, the crop varieties and farming techniques evolved may have ramifications of far-reaching significance.

ICRISAT has primary responsibility for two cereals and two pulses, all major crops of semi-arid tropical regions: sorghum, pearl millet, pigeon peas, and chickpeas. Also, ICRISAT has committed itself to a parallel objective of finding systems of farming that will produce higher output and more dependable results from year to year. The program is still new, and both physical facilities and research projects are in the formative stage. However, the cereals improvement work in sorghum and pearl millet can draw on years of research in India, the Near East, Africa, and the United States. Some work on pigeon peas has also been done in India, Puerto Rico, the West Indies, Brazil, and Australia, and on chickpeas in India, Pakistan, Iran, and other Near East countries. In addition to consolidating the results of these and similar efforts, ICRISAT is forming ties with national and regional centers engaged in related research in the semi-arid regions of the world in preparation for reciprocal program activities.

Sorghum is grown in both temperate and tropical latitudes, with yields in the developed countries about five times as high as those in the tropics. Although the crop originated in the region of Ethiopia and the Sudan and is widely grown for food in much of Africa and in India, the highest level of technology has been achieved in the advanced nations, where it is grown for livestock feed.

Where sorghum is a food crop, wide variations exist in the plant types used by farmers; moreover, consumer tastes differ with respect to grain size, texture, and color. (Sorghum color ranges from pale to dark red or brown.) Most of the varieties now in use in developing areas do not respond to intensive technology. In Africa, sorghum is the dominant crop in areas with low rainfall, whereas in regions with more reliable rains, both maize and sorghum are raised. The sorghums used in Africa are sensitive to day length, which limits the seasons for successful crops. Breeders take factors like these into account when they make selections for the different sorghum-growing regions. Bred-in resistance to pests and diseases is also important to small farmers who cannot afford pesticides.

Intensive breeding research has been under way in India for a number of years. A world collection of sorghum germ plasm, which now numbers upward of 16,000 accessions, is housed near the site of ICRISAT, at the Andhra Pradesh Agricultural University. ICRISAT sorghum improvement teams are using the collection to identify superior lines for given environments as well as specific genes.
for traits they want to incorporate into their best genotypes.

Exchanges of genetic materials and trial nurseries, along with international testing of varieties, are planned as routine activities of the sorghum program. Characteristics being sought include genetic resistance to witchweed, or Striga, which attacks the root system of the plant; resistance to downy mildew and other diseases; and resistance to shootfly, stem-borer, and midge, which head the legions of insect enemies that attack the plant in the field from the time of seed germination through the appearance of the young shoots, flowering, and grain ripening, then after the harvest cause damage to the grain in storage. Resistance to mold in storage is also important if the newly harvested grain has to be kept through the rainy season. Other traits on the wanted list are higher yielding ability; shorter stature, to permit denser plant populations; nitrogen responsiveness; day-length insensitivity; better appearance and texture of grain; higher protein content with higher lysine levels; greater cold tolerance for the high altitudes in the tropics; and tolerance to periods of drought.

Certain high-protein sorghums from Ethiopia hold promise for improving nutritional quality; Purdue University researchers have spotted lines having up to 17 percent protein, with a high percentage of lysine. ICRISAT is multiplying these lines for use in crosses and incorporation into its trial populations.

Superior hybrids previously developed in India have some of the traits being sought by ICRISAT's breeding program, but hybrids have limited value for use among poor subsistence populations. Many countries in dryland areas do not have the capital or technical personnel needed to build up a seed industry and distribution system. Nevertheless, as the lower-income countries progress in economic development and increase the number of trained technicians in the service of their agriculture, they may want to introduce high-yielding hybrids and advanced agronomic practices. For the high-yielding sorghums, physiologists and agronomists are working on such factors as optimal use of solar energy; improvement of cultural practices, including time of seeding, use of fertilizers, and chemical plant protectants; and moisture-conservation techniques.

PEARL MILLET

Pearl millet (Pennisetum typhoides) is only one in a large family of millets; it was selected for special concentration at ICRISAT because of its widespread use as food in South Asia and Africa, and also its superior performance under adverse conditions. Pearl millet tolerates drought and low soil fertility better than sorghum, and in addition it possesses the ability to tiller profusely and to produce two or three ratoon crops in succession. ICRISAT scientists have found that, when sufficient moisture is present, the first and second growth may be cut for forage and the third crop can still produce mature grain.

Breeders' goals—improved yield, stress tolerance, disease and pest resistance, higher protein quality, and acceptable kind and color of grain—are similar to those defined for sor-
ghum. The chief diseases that attack the crop are ergot, downy mildew, and rust, and the millet team is trying to find sources of genetic resistance and incorporate them into the best strains in their working collection. As with other grains, broad-based, or "horizontal" resistance is their goal. Chemical controls are also being tested, with emphasis on low cost, environmental safety, and maximum efficiency. Many kinds of birds are fond of millet, and strong measures must be taken to discourage them in some areas.

The germ plasm collection of pearl millets counts 6,600 entries from a number of countries, including a wide variety from India, and additional sources of genetic stocks are known to exist, chiefly in Africa. A systematic collecting effort will be made as ICRISAT's program proceeds, so that breeders can develop synthetics and hybrids having desired characteristics for various uses and for different growing conditions.

Protein quality in millet varies from 11 to 20 percent, and little work has been done to date to incorporate high protein into the best-performing lines. Hybrids with high yielding potential have been bred, but they are extremely vulnerable to downy mildew; the program is now aiming at development of synthetics, using the method of selection over several generations from a composite population. Such populations are being tested at ICRISAT for yield, agronomic performance, grain quality, and disease resistance; and selections are being made to suit the environmental characteristics of different regions or the needs of local cropping patterns. Yields of over three tons per hectare have been achieved at ICRISAT, and much higher yields are thought to be possible, given good growing conditions. (For people who live under the intermittent threat of famine, however, the prize trait of millet is that it will produce some kind of harvest in the worst of conditions.)

**PIGEON PEAS**

Pigeon pea is grown on nearly three million hectares worldwide, about 90 percent of them in India. World yields average around 600 kilograms per hectare. Experimental plantings have demonstrated, however, that the yield potential of this crop is much higher; up to 5,000 kilos per hectare and more have been grown under controlled conditions, using local Indian varieties. With genetic research concentrated on improve-

*Short-duration, higher-yielding millets are being developed.*
ment of plant type, it is reasonable to expect that even higher yields could be achieved. Total protein can also be increased, since cultivars that range from 18 to 32 percent in protein content have been found.

At present, many of the varieties grown in India take up to 300 days from planting to harvest, but high-yielding experimental plantings have been grown in 150 days. Short-season varieties could be extremely valuable for climates where double cropping is feasible.

Pigeon peas in India are traditionally interplanted with sorghum or millet; they grow slowly at first, then shoot up after the companion grain is harvested, and then take another five months to reach maturity. In addition to the dry peas, which in India are used chiefly in dal (a kind of split-pea sauce or puree), the green pods are edible, and the wood can be used for fuel. The tall plants also have the advantage of a deep root system, which makes them tolerant to drought, and they are fairly resistant to pests and diseases. Plant population density, however, is low, a condition further aggravated by the widespread use of large woody plants that grow to a height of eight to ten feet.

Recent development of dwarf types with determinate growth habit has opened up possibilities for higher plant densities and improved plant types with a higher ratio of grain to foliage. Breeders also have hopes of improving growth in the early stages and developing better resistance to diseases and pests, especially pod-boring insects. Short varieties that can be used to advantage in inter-cropping systems are being sought, since the grain-pulse combination is nutritionally valuable in semi-arid regions where rural people’s diets are generally insufficient and protein levels in particular are below minimum requirements. Agronomic practices adapted to the inter-cropping combinations are also being worked on by ICRISAT’s multidisciplinary teams.

**CHICKPEAS**

India grows about three-quarters of the world’s chickpeas, and Pakistan another 10 percent. Other producers include the countries of the Near East, southern Europe, Africa, and Latin America. Between six and seven million tons are produced annually on some 10.8 million hectares. Yields in India and Pakistan average 300 to 400 kilograms per hectare, whereas experimental yields as high as 3,000 kilos have been obtained in Iran.

Both seeds and pods are eaten; the dry peas are also ground into flour and the foliage used for livestock fodder. Varieties with large, light-colored seeds are most familiar in the Mediterranean region and the West, whereas in the Middle East a small-seeded, black variety is popular. In India and Pakistan, brown and green peas of medium size are preferred. Total protein in chickpeas is about 20 to 22 percent, but as in most pulses, the protein is low in sulphur amino acids, especially methionine.

In India, chickpeas are a winter-season or rabi crop, grown on residual moisture after the main crop has been harvested. It is a plant that thrives in dry weather, and is likely to suffer from a type of fungus blight if too much rain falls; soil conditions can
make a difference in yield. Most varieties in use in the developing countries have a low genetic potential and are susceptible to wilt and blight. In addition, a major constraint seems to be neglect. The crop is customarily planted on marginal soil and given a minimum of care. Farmers used to getting low yields and suffering losses of up to 50 percent do not think it worth their while to invest in insecticides, soil improvement, or irrigation. This profitless cycle might be broken, however, if disease-resistant varieties were available—more dependable prospects for a decent return might persuade farmers to put more effort and money into the crop.

ICRISAT's program is aiming for resistance to wilt, blight, and anthracnose as well as altered plant type and higher protein. The ultimate goal is to combine in a single plant the traits that will give increased production, dependability, and high nutritional quality.

FARMING SYSTEMS

Over vast stretches of land in the seasonally dry, semi-arid tropics on three continents, the traditional farming systems are as diverse as man's hard-pressed ingenuity can devise. Basic differences stem from both natural and social conditions. Small landholdings, subdivided over the course of generations into minuscule sub-plots, predominate in some areas, while in others communally worked lands are more usual; in others, tenants work fractions of large estates, a part to pay their rental fee and a part for their own needs. There are still other regions where land owner-ship is ill-defined, and semi-nomadic people farm an area for as long as it will feed their families and flocks, then move on. The timing of the monsoons and the amount of rain they bring, the types of soil and the shape of the terrain, as well as the local customs and the availability of labor, implements, and power, all influence the choice of crops sown and determine when and how the planting is done, how well the crops are cared for, and what becomes of them after the harvest.

To develop basic farming patterns that can be recommended for reasonably wide areas, ICRISAT is conducting research at its headquarters site and is also seeking the collaboration of agricultural centers in other countries for assistance in gathering information, testing various cropping combinations and agronomic practices, and eventually, disseminating research results.

A common denominator throughout the area is the need for efficient water management. Low rainfall and water scarcity are the most conspicuous drawbacks, but short periods of excess rain, especially on soils with poor drainage, can ruin crops, carry off topsoil, and leach out nutrients. Monsoonal climate is by definition unpredictable and given to extremes. Excessive rainfall at the wrong time can bring insect infestation or virus disease just when the plants are most vulnerable to them; dry periods occurring in the middle of the rainy season can wilt the monsoon crop, or too much rain in winter can damage the dry-season plantings.

Practical water catchment and drainage systems that could be economically and simply built would do
much toward mitigating the effects of uncertain rainfall. ICRISAT is starting with a series of experiments on small watersheds, using catchment ponds and grassed waterways, and comparing the effects on two major soil types—red, lighter-textured soils and heavy, black soils—which predominate in rainfed farming areas. Soil and agronomic research include work on erosion and nutrient loss; weed control, mulching, and shallow tillage following the harvest; double cropping and relay cropping. Land shaping and flat or ridge planting on graded contours are being tried as aids to water retention in the soil and control of erosion.

Since ICRISAT's program is beamed toward capital-scarce economies that have an excess of rural labor, the technological recommendations will be scaled accordingly. A prime objective of the production package has to be dependability, since the many hazards of arid-land farming have conditioned producers to prefer practices and crops that entail little risk, even though they do not promise extraordinary rewards. The indispensable requisite, from the Institute's point of view, is that the package elicit interest and willingness to cooperate on the part of farmers.

**TRAINING**

A training program is planned in connection with research. In ICRISAT's first full season, students in agricultural engineering from Punjab University were recruited to work on farm layout and land development in the summer of 1973. Short and long-term arrangements for scholars, visiting scientists, and trainees will eventually be integrated into ICRISAT's schedule of activities; liaison with a number of institutions has already been established for this purpose.

**OUTREACH**

Extension of the results of ICRISAT's research, exchanges with other centers, and field projects in cooperating countries are likely to take on major importance as the Institute's work gains momentum. ICRISAT is already in contact with a number of centers in India, the Near East, and Africa; and a UNDP global project in sorghum and millet is supporting research and training projects aimed at improving these crops and providing production assistance wherever they are grown.

ICRISAT's programs are focused on what have been, up to now, neglected crops, neglected regions, neglected rural populations. International support, top scientific talent, and advanced technological resources are being marshaled to serve needs that are none the less crucial for having long been disregarded. The task is difficult, bearing the unmistakable stamp of high challenge.
El Centro Internacional de la Papa (CIP), the International Potato Center, is a one-crop institute; its mandate is to improve potatoes and potato growing in developing countries and to extend the potato’s range of adaptation to new territory, including the lowland tropics. The potato in question is the white or Irish potato, the tuber-bearing species *Solanum*.

CIP is relatively new in the institute network, but it has precursors 10 and 20 years old. The oldest is the Rockefeller Foundation’s International Potato Program, a collateral descendant of the cooperative agricultural program in Mexico that led to the establishment of CIMMYT. That program was merged with a potato research effort which had been under way for a number of years in Peru in cooperation with North Carolina State University, under a USAID contract. Both these forebears provided CIP with a legacy of research results, trained people, ongoing projects, and valuable biological materials on which to build its program. Since its establishment in 1971, CIP has integrated these assets into a wholly new battle plan.

The Center’s leaders have designed an innovative scheme in which CIP figures both as a high-level experimental station in the conventional sense and as a center participating in research and action programs around the world. For this reason, it is putting a smaller proportion of resources into developing its headquarters facilities and investing more of its energies and funds in research and production programs in other countries, both developing and developed. This approach involves less in the way of initial installations and equipment, and greater emphasis on building coordinative, administrative, and strategic capability.

**STRATEGY**

CIP’s approach is in three dimensions. The first is research into ten major problem areas, the program thrusts to which CIP has committed its energies and resources. The second is outreach activity in geographical zones of the developing world, each one mapped for potato problems and potentials. The third is the research projects conducted by CIP staff and by other scientists under contracts with the Center, which form a mosaic of individual and team efforts closely related to the major program thrusts and the designated priority zones.

CIP’s professional staff conducts research at the headquarters station at La Molina, just outside Lima, and
at two other locations in Peru, one at an elevation of 10,000 feet, at Huancayo, and the other at sea level in a tropical rainforest environment, at San Ramón. In addition, the Center contracts with institutions in the United States, Mexico, the United Kingdom, and countries of Western Europe for work on specific projects that are relevant to its sharply focused research objectives. Adaptive research will be conducted in developing countries through the outreach program. Eventually this aspect of the work will comprise a network of cooperating national and regional potato efforts, coordinated through a system of local centers manned by teams of CIP scientists. CIP expects to have staff stationed in most of the key locations by the end of 1974.

CIP's plans are drawn in consultation with the world's top potato men. Periodic planning conferences or workshops are held under the Center's auspices, at which world authorities analyze the status of research and the outstanding needs in their specialized fields. In this way high-level scientific knowledge and expert judgment are funneled into the Center's evolving strategy, and other institutions are able to define their objectives and plan long-range programs on the basis of the pooled data. These summits, attended by CIP senior scientists and about 10 to 15 invited specialists from other countries, help determine where program emphasis will be placed—what projects, research areas, and regions will receive immediate priority in terms of funds, staff time, and outreach effort. Planning conferences have dealt with the key problems and potentials for increasing the use of potatoes in the developing world; late blight, the number-one potato disease; bacterial wilt; potato quality; resistance to potato cyst nematode; cold resistance; and utilization of genetic resources and seed production technology for developing countries. At the conferences, five-year plans are drawn for coordinated activities in the particular aspect of research under discussion; a review after the first three years ensures continuing relevance and flexibility of specific projects and of the general orientation of the investigations.

An important consideration in the determination of program priorities is the possibility of establishing bridgeheads—for example, the imminence of a breakthrough in a specific line of research or the likelihood of making a significant impact on production in a given geographical zone. Food needs and developmental needs in the various nations are weighed realistically against known restraints, such as a lack of trained technicians, a top-heavy bureaucracy, or an uncoordinated agricultural sector. CIP's forces are limited, and its leaders intend to use them to the utmost advantage.

**POTATOES**

Potatoes are the world's fourth most important crop, after rice, wheat, and maize. They are grown chiefly in the temperate-zone, advanced countries, where they are the staple food of the poor as well as an important element in the diet of the whole population. Technologists have devised new ways of processing and preserving potatoes, which have extended their
usefulness and versatility for consumers in the industrialized nations; in most developing areas, however, they are still known as a luxury food.

Like a great many of the world's major agricultural products, potatoes have attained their widest use and importance in lands far from their place of origin. They were first introduced into Europe by the Spaniards in 1570 and have been selected and adapted over the years for the growing conditions in the cool-climate countries of northern Europe, the British Isles, the USSR, and North America, but their native place is the Andes mountains. Potatoes originated, scientists believe, in the intermediate and high-elevation slopes and plateaus of Mexico, Central America, Colombia, Ecuador, Peru, and Bolivia. Untapped genetic resources, both wild and cultivated, still exist in this region, but they are slowly being eroded, in part by expanding agricultural development and other harbingers of progress—roads, airfields, human settlements. Logically enough, the research thrust at the head of CIP's list is collection, classification, maintenance, and distribution of all tuber-bearing *Solanum* species. Only about 5 percent of the genetic variability of *Solanum* has been used in the development of the potato varieties now widely cultivated.

The potato has made very little progress in the world's hunger belt, where it could add substantially and advantageously to food supplies with its high food yield per acre, its ample carbohydrate content, well-balanced protein, and high levels of Vitamins C and B. In hot climates, however, diseases and parasites are major drawbacks to production, particularly where chemical protectants are too expensive for farmers to use; tropical conditions make storage difficulties greater for potatoes than for grains or legumes; and tuber seed multiplication and distribution present technical and economic problems in countries that lack the necessary training base and infrastructure. Nevertheless, potato research and technology are rapidly approaching the stage where accelerated production programs can be mounted in key areas, and from there, CIP's strategists project, they could be systematically extended to neighboring countries.

**Th e r e s e a r c h a r e a s defined by CIP for major concentration begin with development of the world potato collection. Accessions in the germ plasm**

*Physiology work is carried out at La Molina laboratory.*
collection now number more than 5,000. These are chiefly cultivated clones from the Andean area, although 700 examples of wild species are also part of the world collection. CIP had two collecting teams in the field in 1973, and five expeditions have been planned for 1974. Approximately 8,000 samples from the collection have been sent out to scientists in 31 countries.

This genetic material is being screened and the information coded for computer retrieval. The collection is maintained in clonal form by replanting yearly; it is also being converted to disease-free true (or botanical) seed, for storage over periods of 20 to 25 years.

The second research thrust is the development of breeding techniques to provide better adapted potato varieties for use in developing countries. Research at CIP headquarters is coordinated with projects at North Carolina State University, Cornell University, and the University of Wisconsin. The breeding programs are aiming to synthesize the diverse genetic resources into potentially useful genetic combinations. Their goal is to produce populations from which clones may be selected for a wide range of environments. Some of the traits that are the object of the research in these four locations are frost resistance; high energy content of tubers; resistance to major diseases, insects, and nematodes; wide adaptation to day length; and high yielding ability.

Control of fungal diseases, defined as the third major program thrust, is focused chiefly on the search for genetic resistance to late blight and studies of the various races of the fungus that causes it. Almost every known strain of the pathogen exists in the Toluca valley of Mexico, where the Rockefeller Foundation’s potato program screened thousands of potato varieties and identified material having multi-gene resistance. Further breeding using these sources of resistance is being carried out in developed countries, and some commercial varieties having this trait are coming into use. Screening is in progress at Huan-cayo and San Ramón as well as in Mexico.

Control of the bacterial diseases is focused primarily on studies of bacterial wilt. A source of resistance to this disease was found in Colombia, and it now forms the basis of material that has been multiplied at the University of Wisconsin for international testing. The first trials have gone out to stations in Peru, Costa Rica, Colombia, and Brazil.

A project at the University of Wisconsin is aimed at combining resistance to late blight and to bacterial wilt in a single potato clone. The diseases often occur together, constituting a major obstacle to potato production in most lowland tropical regions. Promising lines with resistance to both diseases have been sent to 18 countries for testing, and new varieties may soon be released.

Viral diseases and insect vectors are another major research area. There are 20 known virus diseases of potatoes, and many more unidentified. High priority is given to screening for viruses that may infect breeding material. Seven viruses head the list, and of those potato virus Y and leaf roll are under intensive study. To date 2,500 clones from the germ plasm col-
lection have been evaluated to detect the presence of the major viruses.

Nematodes, in particular the cyst nematode (*Heterodera*), attack potatoes in many areas. At least ten strains of this pest are present in Peru, and it is prevalent throughout the Andean area. CIP has undertaken a screening program of materials from its germ plasm collection as well as from interested countries. The testing involves four strains of the nematode, and materials are rated for both resistance and tolerance. Other nematodes under study are the false root-knot nematode (*Nacobbus*), which is a nuisance in cold climates, and the root-knot nematode (*Meloidogyne*).

Attention is also being given to development of potatoes with wider adaptation to environmental stress and resistance to insect pests. The role of insects in virus transmission is being studied at CIP, where the germ plasm collection is being screened for sources of resistance to the main vectors, such as the green peach aphid and the potato aphid. Other insects under study include leaf hoppers, leaf miners, and weevils. Both cold tolerance and adaptation to the hot, humid tropics are being sought, the former through studies at high elevations in Peru and Colombia, and the latter, through the experimental work at San Ramón. For potato growing in cold climates, a solution might be found through the development of early-maturing varieties which can be harvested before the onset of frost. Clones with a 100-day season have been grown in Peru. (Normally 150 to 180 days are required to grow Andean varieties.)

Per hectare, the potato produces more protein than the major cereals. Potato protein quality is good, and clones with 11 to 12 percent protein on a dry-weight basis have been identified in the CIP germ plasm bank. The potential for breeding potatoes with even higher protein content is considered excellent: clones with 20 to 25 percent of the dry matter as protein are known.

Seed production technology must be evolved for developing countries before accelerated potato production programs can be contemplated. For this purpose, CIP is working on tissue culture for disease elimination and on measures that will permit rapid multiplication and distribution of new clones. Seed of varieties that are free of viruses are being multiplied, and clones resistant to wart disease, blight, and several fungal and viral diseases are ready to be processed. In many countries, training in seed production will be necessary to build up local technical capacity for seed industries.

**PROJECTS**

CIP counts the projects under way both at home and abroad as part of its core program. In funding research at experimental centers in the developed countries, CIP can draw on a broad range of expertise and can benefit from sophisticated equipment and experimental facilities it would not otherwise have access to. This collaboration offers reciprocal advantages, since findings in any one of CIP's research areas may be of value to potato growers in the developed countries as well as to the advancement of CIP's program goals.

CIP keeps close track of research
in progress, both internal and contractual, through periodic program reviews, in-house seminars, and evaluation of written records and reports. Projects may be carried out by one researcher or several; most involve more than one specialist and more than one discipline. As a result, each CIP scientist is usually engaged in two or three ongoing projects. The team draws up a detailed outline, spelling out its needs in terms of staff time, materials, land, and other resources, and in the course of the work submits reports on its activities and progress.

**Rehabilitation**

The outreach program is one of the most important aspects of CIP's work. For the present it is in the formative stage; preliminary surveys of the target countries have been made, and CIP staff members have been assigned to several overseas regions, where they are working with national leaders toward development of local programs. Training courses, generally dealing with the use of disease-free breeding materials, seed multiplication, and commercial potato improvement, have been held annually since 1972 in Peru, Mexico, and Kenya. The first annual training school for the Middle East region recently held in Egypt. Broad goals of the program thrust include design, research adapted to the needs of the various regions, training of local scientists and technicians, and efficient distribution and utilization of potato technology to the needs of the small subsistence farmer.

CIP has divided the developing world into seven target zones which cover both hemispheres. Each zone has been assessed for characteristics that have a bearing on potato production, from climate to degree of interest in agricultural development, and further investigations are being focused on specific factors such as ecological conditions, consumer preference, marketing structures, and similar considerations which are important in determining the types of germ plasm to be selected for trial in various areas. CIP's intention is not simply to produce varieties, but to furnish materials for trial, and further development in each zone, so that local programs can ultimately release and name their own varieties.

When the outreach program is
fully operative, a program center in each of the seven zones will have a skeleton staff from CIP. Its primary mission will be to cooperate with local leaders in strengthening national capabilities, so that the countries in the region can benefit from the new technology and improved germ plasm made available through CIP.

TRAINING

CIP has an agreement with the Agrarian University, located near its headquarters in La Molina, under which Master’s degree candidates can do their thesis research in connection with one of the Center’s programs. Similar arrangements with institutions in developed countries allow Ph.D. degree candidates to do a major portion of their thesis work at CIP. Postdoctoral scientists are also accommodated in CIP’s laboratories for work on projects related to the Center’s objectives.

Training for national potato program leaders and technicians for the developing world is being conducted at the outreach centers; formal classroom instruction linked to firsthand planting-to-harvest experience in growing a potato crop is the basic formula around which the educational programs designed by the Center are structured.
South of the Sahara Desert are vast stretches of range and grassland, but cattle raising in these areas is hazardous. Two diseases, trypanosomiasis and East Coast fever, afflict livestock in over four million square miles across a wide belt that spans the African continent from the Indian Ocean to the Atlantic and reaches southward from the Sahara to roughly the level of the Zambezi River. Trypanosomiasis infects three-quarters of the area, and East Coast fever an estimated one-fourth. Both are blood-borne parasitic infections, the first carried by the tsetse fly and the second by ticks. Exposure of susceptible cattle to either one can mean famine for nomadic herding societies that depend on cattle for their food, or ruin for small ranchers whose animals are their livelihood.

In Zebu cattle, which are fairly resistant, East Coast fever can take a routine toll of up to 15 percent of the calf crop in endemic areas, with the adult population immune; in susceptible stock, entire herds can be wiped out. Trypanosomiasis takes several different forms; it can be swift or lingering, and in either case it can be fatal. Certain wild species of animals as well as domestic stock succumb, making a valuable resource for both food and export products virtually unexploitable in over a third of the continent. Estimates hold that the territory occupied by the tsetse fly could support 200 million head of cattle.

About 30 developing countries lie wholly or partially in the infected area. Control of these two diseases could make a radical difference to their economies and improve the lives of thousands of their people. A number of methods are currently in use—tick dips, insecticides, bush clearing, slaughter of wild animal hosts, preventive drugs—but none has been completely effective. A vital breakthrough would occur if vaccines against the two diseases could be developed. The progress of immunology in recent years holds out real hope that this can be done.

FOCUS OF RESEARCH

In 1973 the Consultative Group on International Agricultural Research concluded a Memorandum of Agreement with the Government of Kenya, establishing the International Laboratory for Research on Animal Diseases (ILRAD), to be located in Nairobi. ILRAD’s primary and most urgent
purpose is the development of immunological procedures for the prevention of trypanosomiasis and East Coast fever, which are so destructive to cattle.

Heretofore, attempts to control these two major hemoprotozoan infections have met with limited success because of gaps in our knowledge of the causative organisms, their pathogenicity, and the host responses. For example, variation in the antigenicity of trypanosomes makes it possible for these organisms to survive and multiply even after the hosts have developed an immunological response to the original invading forms. Trypanosomes apparently possess the capacity to change their surface coat, thus becoming insensitive to the effects of antibodies. There are several new and fundamental approaches to this problem, and some very hopeful leads for potential immunization have been developed.

Recent advances in the immunology, molecular biology, and ultrastructure of these organisms have raised the hope that trypanosomiasis can ultimately be eradicated from large areas of Africa, provided that intensive research can be conducted on the basic biological aspects of these parasites. Although many investigators in different parts of the world are conducting active research on these diseases, the solution to these problems will be greatly facilitated by the existence of a coordinated, multidisciplinary, intensive program conducted in a single institute located in one of the endemic areas. The combined knowledge of zoologist, biochemist, geneticist, immunologist, and pathologist will doubtless increase the probabilities for success in understanding and overcoming the problem of antigenic modulation, toward the ultimate goal of providing safe and practical vaccines.

The laboratory is being organized into five departments: Zoology; Immunoochemistry and Cellular Immunology; Molecular Biology and Genetics; Cultivation; and Pathology and Ultramicroscopy. In support of the research program, ILRAD will have specialized facilities at its disposal, including veterinary and radiobiological services, a library and documentation center, and audiovisual and biometric services.

ACTIVITIES

In pursuit of its objectives, ILRAD will conduct basic and applied research; test results in the field; publish and disseminate research findings; and establish contacts with other laboratories and research groups in order to exchange information, avoid
duplication, and determine priorities in animal health problems. It will also organize discussion groups, seminars, workshops, and conferences; conduct formal and on-the-job training of scientists and specialized technicians; and assist other institutions in applying the research results of the laboratory.

Research and educational organizations already exist in many parts of Africa, and ILRAD will seek to develop close working relationships with interested institutions where facilities permit. In particular, an active research program on East Coast fever is currently in progress at the East African Veterinary Research Organization (EAVRO) in Muguga, Kenya, supported jointly by the UNDP, FAO, and East African Community.

Training at the postdoctoral level is among the major proposed activities of ILRAD. Although the laboratory will not be a degree-granting institution, it will work with universities in Africa and other parts of the world and with other research centers that have similar objectives. Provisions will be made to accommodate established investigators who wish to devote their sabbatical years to studies that fall within the purview of ILRAD's objectives, as well as visiting scientists assigned to specific projects, and graduate and postdoctoral students who seek advanced training in animal parasitic diseases.

A basic operational principle is to provide scientific and training assistance to help develop and strengthen national institutions and ongoing programs. ILRAD also will serve as a link between African research centers and the highly specialized laboratories in the developed countries. The combined efforts of ILRAD and the new International Livestock Centre for Africa (ILCA), are expected to improve Africa's livestock production through a sustained assault on the major production barriers.
In 1974 the Ethiopian Government and the World Bank, acting on behalf of the Consultative Group, signed an agreement for the establishment of the International Livestock Centre for Africa (ILCA). ILCA's purpose is "to assist national efforts which aim to effect a change in the production and marketing systems in tropical Africa so as to increase the total yield and output of livestock products and improve the quality of life of the people in this region."

ILCA's three main areas of activity are formally defined as research, training, and documentation.

The livestock population of tropical Africa includes about 130 million cattle, 100 million sheep, and 80 million goats, but production levels are far below the industry's estimated capacity. Animal production nevertheless represents an important element in the economy; its value has been estimated at over U.S.$1 billion annually, or about 5 to 6 percent of the gross domestic product of the region. With urbanization and economic development, added to growing populations, the demand for milk and meat is rising rapidly, foreshadowing severe shortages within the next decade unless energetic measures are taken to accelerate the growth of animal industries. The average per capita consumption of meat in Africa was reported by the FAO to be 9.4 kilograms in 1970; it is expected to rise by little more than one kilogram in 10 years, to reach 10.8 kilograms in 1980.

Even if the growth rate of meat production (which was 2.7 percent a year in the 1960s) could be raised to the target level of 4.3 percent set as a goal by FAO's Provisional Indicative World Plan for Agricultural Development, shortages would still amount to over a million tons of meat and 700,000 tons of milk. A dynamic livestock industry could contribute much to economic development of the countries of tropical Africa as well as to improved nutrition of their populations. General avenues of approach include opening up unused land for ranching; improving the feed base, including grazing lands and pastures; and upgrading herds and management practices.

ILCA's activities will ultimately embrace interdisciplinary programs aimed at all these objectives.

**PRODUCTION PROBLEMS**

On all but a few modern ranches, animal production throughout Africa's tropical latitudes exhibits a familiar combination of shortcomings.
Calf mortality is high; animals are poorly nourished—some are semistarved in the dry season—and growth rates are slow; poor health and exposure to environmental stresses result in low market weights and low annual oftakes. Determining the elements of proper livestock management for tropical Africa's diverse environments and persuading cattle owners to adopt them is matters of considerable complexity.

In spite of physical, biological, and economic limitations, Africans produce meat by raising cattle, sheep, and goats. Their techniques are simple, but they contain a certain degree of adaptation to unfavorable conditions. Nomadism and transhumance are dictated by the cycles of the rainy and the dry seasons; the overstocking of old cattle is a way of preserving stocks, as only strong animals survive drought and diseases and are able to reproduce.

The widespread use of very effective vaccines against rinderpest, pleuropneumonia, and practically all viral and bacterial diseases has permitted a much larger growth in the number of cattle during the last 30 years than during the period 1860-1920, during which time more than three-quarters of the herds died from these diseases.

There still remains, however, the problem of trypanosomiasis tick-borne disease, and in particular East Coast fever, which prevents the development of a large cattle industry in the humid areas of Africa.

Traditional techniques are unable to cope with the increasing demand for meat due to the growth of population and at the same time, owing to the development of agriculture, less land is available for livestock raising.

The recent drought has shown dramatically that something has to be done. Technical solutions to the improvement of livestock production have been discovered in Africa and other tropical areas, but they have been applied in only a very limited way, possibly because their application involves factors that have not been integrated into the total system of production.

To improve animal production and animal health, it will be necessary to modify considerably the outlook of the owners, and to motivate them to make the necessary changes. To achieve this, multidisciplinary teams will be required, involving a wide range of specialties including breeding, nutrition, and herd management; conservation and improvement of grazing lands; analysis of economic...
factors bearing on livestock operations, including marketing and processing of animal products. Anthropological and sociological studies will be necessary to help devise training, demonstration, and extension tactics that will be meaningful and persuasive to herdsmen and ranchers. New approaches will have to be found for working with herding societies; their way of life has been disrupted by the evolution of crop and industrial agriculture, and they have not yet found the means of dealing with this disruption.

For the most part, the land devoted to the cattle industry in Africa cannot be used for cropping, owing to the absence of agricultural soil, insufficient yearly rainfall, or the lack of deep water in the dry season. In these regions, particularly the Sahel, men could not live without livestock.

Under such conditions it is not surprising that in many places deterioration of range land has occurred and water resources are endangered. The severe drought of the last ten years has resulted in overgrazing, which has led to severe erosion of range lands; the vegetative cover in some places is now so sparse that it may be years before it can be regenerated.

The application of available technology could considerably improve this situation, although certain problems, such as those arising from climate and water scarcity may be next to impossible to overcome; others, like the prevalence of tropical diseases (trypanosomiasis, tick-borne fevers) may require long and expensive research; cultural patterns and deeply ingrained attitudes also take years to be reconciled with the forces of change.

A number of organizations and governments have carried out campaigns to develop production systems for limited areas and to teach pastoralists and ranchers to conserve water, use their grazing lands more rationally, protect their animals from disease, and observe simple rules of good husbandry. Research has also been carried out in numerous institutions in both the English and the French-speaking zones, demonstrating that the potential exists for a greatly improved animal industry. No attempt has been made, however, to assemble the results of such training, extension, or research programs into a collective documentary resource, or to integrate them to form a matrix for policy formulation or action programs.

Some of these efforts have had considerable local impact. For some years the need has been felt for a co-ordinative agency with high-level support and prestige, which could assist national livestock programs; supplement and strengthen ongoing projects without duplicating the work already done; make existing knowledge available to workers in the field in both major languages; stimulate research and action where possibilities for improved performance are recognized; and make a systematic effort to identify additional areas that have good potential.

ILCA'S PROGRAM

ILCA's mandate covers both the biological and organizational constraints to improved livestock production in the tropical countries south of the Sahara. Its staff is assembling and evaluating the available information
in the animal sciences as a preliminary step to designing a research strategy that will fill the gaps in present knowledge. It is analyzing the elements necessary for undertaking multidisciplinary studies and incorporating the team concept in projects to be initiated under its auspices. This is a bold step in a field that is relatively isolated from other branches of the agricultural sciences and within which individual disciplines are traditionally self-contained and compartmentalized. ILCA’s leaders plan to coordinate the efforts of animal scientists, sociologists, ecologists, economists, and others engaged in studies of the man-animal-environment complex.

Two types of program will be sponsored: *integrated projects* organized by ILCA, in which the efforts of researchers from different disciplines will be orchestrated to achieve a clearly defined objective; and *associated projects*, which will be proposed and carried out by cooperating institutions in the various African countries. Projects in the animal sciences will include genetics and physiology, nutrition, reproduction, adaptation to climate, and epidemiology. Environmental studies will be conducted on weather and soils, the ecology of range lands, and range and pasture improvement. The socioeconomic component of the program will focus on the geography of livestock raising; the social structures, cultural attitudes, and value systems of pastoral societies; economic analyses of livestock operations, marketing systems, and the relationships between producers and consumers. Data from these studies will be applied to the development of integrated models for different types of range management.

ILCA’s role in training animal scientists for the African tropics is of paramount importance. The numbers of professionals in veterinary medicine and animal health are growing in most countries of the region, but Africa needs more training at university level in animal production, range management, economics, marketing, and related fields. Scientists and technicians are needed in every branch of livestock production in every African country; moreover, training of leaders with an interdisciplinary orientation and a broad understanding of developmental objectives in the livestock industry is of the utmost importance. Young scientists will be associated with ILCA-sponsored research programs, and studies in relevant fields will be promoted at the undergraduate and graduate levels through cooperative arrangements with universities in Africa and abroad.

Seminars, conferences, in-service courses, and similar activities carried out under ILCA’s auspices will contribute to education, exchange of information, and airing of problems at different levels and in different areas of interest. ILCA will also offer consultative, documentary, and statistical services to national, regional, and international organizations dealing with improvement of animal production in Africa. Contacts will be maintained with the International Laboratory for Research on Animal Diseases (ILRAD), whose program objectives complement those of ILCA.