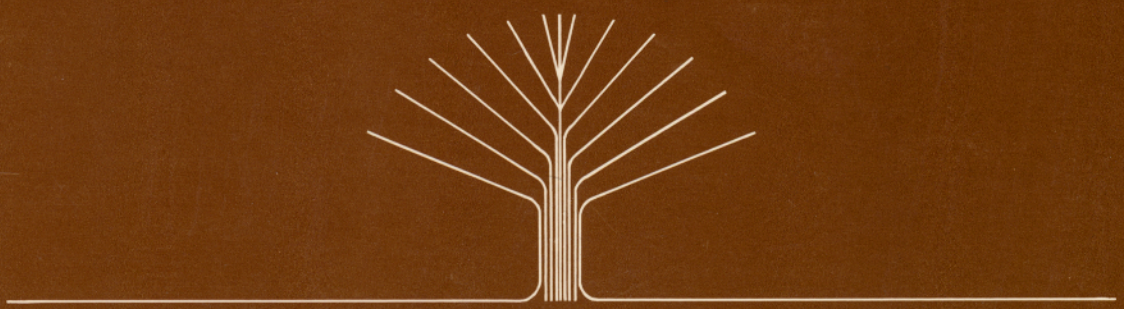
The Fragile Web

The international agricultural research system



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Foreword

In the 1960s, the outlook for world food supplies was bleak. The gloomy statistics of rapid population growth and sluggish food production caused great concern. Most of the world's arable land was under the plow. Expanding onto less suitable, marginal lands involved greater risks, expensive improvements, and more demanding management than was within the reach of farmers in the developing countries where food was most urgently needed.

Intensifying production on existing lands appeared to be the only solution, and the application of improved agricultural techniques the means to achieving it. Thus in 1971, the Consultative Group on International Agricultural Research (CGIAR), an informal consortium of governments, international and regional organizations, and private foundations, was established to nurture agricultural research to improve the quantity and quality of food production in the developing countries.

From the beginning, the International Development Research Centre (IDRC) and the Canadian International Development Agency (CIDA) were involved as members of the founding Group, which was sponsored by three UN bodies: the World Bank, the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Development Programme (UNDP).

Although CGIAR has grown from a core of 15 donors contributing US$ 12 million to four centres in 1972, the full first year of operations, to the present 35 donors contributing US$ 149 million toward the support of 13 research centres, it has retained its unique "noninstitution" role. It does not operate with a legal charter, or codified rules, but with the common consent of its members that their purpose is to consult and agree on ways and means of supporting international agricultural research.

The original idea behind CGIAR and the international centres that it supports — to concentrate on agricultural research and allocate resources more effectively — remains intact, because this network of autonomous, independent research centres has successfully kept itself free from the pressures of governmental policies.

As it enters its second decade, CGIAR can look back to the conservation and exploitation of genetic resources as prime among the contributions the system has made to agricultural research. More than half of the centres' work has been in the area of breeding and improving varieties of food and pasture crops.

Beyond the crops themselves, CGIAR's work on farming systems and the components of increased productivity has been substantial. Recognizing the need to reduce dependence on purchased inputs such as fertilizer, member centres have developed farming systems to aid farmers working with limited financial, climatic, or soil resources. There is a growing emphasis, too, on research to improve African livestock production and marketing systems and to develop effective controls for major diseases that affect livestock in the tropics.

For the future, members of the system foresee a tighter focus on research on food crops and cropping patterns of importance to poor farmers who still labour largely outside the established production and marketing networks. Millet, lentils, and other pulse crops and root crops such as yams and cassava are grown in complex cropping patterns. And when animal or tree crops are added, and the whole divided into the millions of smallholdings in the developing world where production gains are urgently

needed, it is apparent that the next decade's work presents no less a challenge than the first.

Inflation, tight money, and the ongoing questioning of strategies and modes of operation also lie in the future for CGIAR, as they do for all international organizations. And its greater task — to help bring about the annual increases in agricultural production that are necessary to keep the world fed — takes on increasing urgency. Fortunately, in a way that few other organizations can claim to be, the CGIAR and the international agricultural centres appear equal to the challenges.

It is to highlight the work of the first decade of the CGIAR and the challenges of the next that IDRC and CIDA, with the assistance of UNDP, take great pleasure in presenting this account of the achievements and plans of the Group and its associated centres.

Joseph H. Hulse, *Vice President, Programs,*
International Development Research Centre
and
Douglas D. Lindores, *Vice-President, Multilateral Branch,*
Canadian International Development Agency

Beyond Survival

No activity so preoccupies the human race as the production, preparation, and consumption of food — not making war, nor making love, nor even making money. The reason, of course, is simple: whatever we do, whether in love or in war, we must eat to survive.

Humans are complex biochemical organisms of a fairly inefficient design. They need constant inputs of the right kinds of fuels just to maintain body temperature, circulation, and respiration. They are prodigious consumers of food energy, a great deal of which is expended simply in obtaining more food to provide more energy.

In this, of course, humans are no different from most other forms of animal life on this planet. Where they differ is in their ability to produce food. Tens of thousands of years ago, they left

Cultivation: socialization and a step beyond survival of the fittest.

the forests and learned to cultivate the plains. This development allowed humanity to multiply beyond the "natural" limit and led inevitably to *Homo sapiens*' becoming the dominant species on earth.

The invention of agriculture signaled the beginning of the end of a biological system based primarily on survival of the fittest. Puny humans came to dominate far larger and stronger creatures and turned that domesticated strength to their benefit. They and their communities multiplied and spread everywhere on earth that was capable of supporting agriculture.

Agriculture meant socialization, which meant division of labour, and the necessity for trade and commerce, organization, and regulation. They, we, became an ordered, though not always an orderly, race.

But now the order is changing. We have evolved and multiplied, and our technologies have evolved and multiplied. We are increasing at a rate of perhaps 70 million each year. Still, our technologies, our skills, our inventiveness have enabled the farmers among us to stay ahead of our apparently endless fertility. But only just, and only most of the time.

Slowly, some say inexorably, we are outgrowing our ability to feed ourselves. There are three main reasons that experts believe we are in danger of running out of food. First is the population explosion. Second is the ironic fact that successful development programs leading to a higher standard of living lead also to an increase in the demand for food. And third is the fact that most of the world's best agricultural land is already in production.

Population The headlines say "Population Bomb Defused," but the media fail to realize that the "population bomb" went off generations ago, that what we are suffering from now are the shock waves from the explosion. It is estimated that the world's population reached 1 billion about the year 1800. It reached 2 billion about 1930 and 4 billion about 1975. Sometime in the 1970s, the rate of growth finally began to slow,

The population "bomb" exploded generations ago.

falling below the 2% level for the first time. It is now thought to be 1.7%. Even at this rate, the world's population is projected to reach 6.1 billion by the end of the century — that is, one thousand five hundred million more people to be fed in the next 18 years. Just to keep pace with the present, inadequate level of food supply would require an additional 30 million tonnes of grain alone each year. And we are not keeping pace. In 1981, more than 100 countries consumed more food than they produced. African countries actually consumed 10% less food than a decade earlier. By the year 2000, the world's farmers will need

to produce twice as much food as they did in the 1960s just to meet the demand at today's level, and today's level is unlikely to be enough.

Increased demand Development brings with it a measure of prosperity, and people with a little extra money tend to spend it on food. Studies have clearly shown that, as income levels rise, so does the demand for food. In fact, demand rises faster than domestic food production, so food imports also increase. A survey of the 16 developing countries with the fastest growth rates in production of food staples over a 15-year period showed that they collectively increased their imports of those same basic foods over the same period. An inevitable result of this trend is that food prices increase, and the poor, nonfarmers, already malnourished, face absolute poverty, even starvation. Another result is that the major food-exporting countries must continually increase their productivity if they are to meet the demand from rapidly developing countries.

Agricultural land Will the exporting countries be able to meet the demand? In the past, the expansion of agriculture meant simply the cultivation of more land. No longer. The best agricultural land is now under the plow, and, although there are still large regions with good agricultural potential — such as the Indus Delta, the Sudan, and the Gangetic plain — they require enormous investments of both capital and political will to realize their full potential. Meanwhile, we continue to lose arable

People with a little extra money spend it on food.

Technology has planted seeds of optimism.

land to urbanization, industrialization, soil degradation, and desertification. The spread of the desert alone claims 6 million hectares each year, and highly intensive agriculture can be so destructive of the soil that food exports are being termed topsoil exports. The aggregate amount of land under cultivation is expected to increase by only 4% in the next two decades, whereas production must increase by 60%.

Despite this apparently gloomy picture, there is hope for the future supply of food. Optimistic experts predict that we have yet to come close to achieving maximum production from present agricultural lands — let alone lands that have yet to be cultivated. The key to their optimism is technology. It was technology that enabled the world's farmers to increase production by 26% during the 1970s (for the developing countries, the increase was actually 33%). Agricultural science produced new

The desert claims 6 million hectares annually, but efforts are under way to stem its advance.

seeds, new tools, and new techniques to enable farmers to obtain more food from the same land and helped to prevent some of the waste that normally occurs in storage and processing.

All this scientific progress did not come about by happenstance. It is the result of a concerted global effort that was led by a group of several hundred scientists of many nationalities working through a network of research facilities unlike any the world has seen before. These research centres, and the men and women who work in them or were trained in their laboratories and experimental plots, form a unique and fragile web that binds together both developed and developing countries in pursuit of a common goal: food for all.

The Fragile Web

The visitor to 1818 H Street, the big, bleak Washington edifice that is the front door to the World Bank, is directed around the corner to another, more impressive entrance on 40th Avenue. Here, a polite security guard looks frankly puzzled when asked for the location of the Secretariat of the Consultative Group on International Agricultural Research (CGIAR). The name of one of the staff, however, eventually elicits a room number, and a visitor's pass. From there, it is only an elevator ride and a few minutes' trek along carpeted corridors to a small suite of offices in the far corner of the 10th floor of one of the interconnected buildings that make up the World Bank complex. This is the headquarters of the CGIAR.

Most bureaucracies, given a few years and a steady inflow of cash, have a tendency to take on a life of their own and proliferate like weeds in a newly plowed field. "The CG," as it is almost invariably known, is an exception, although its secretariat is about to undergo a 40% expansion. The change will only increase the number of professional staff from five to seven. After 10 years, in which the budget has seen a six-fold increase, the CG is hardly a burgeoning bureaucracy.

The CG is as unusual as its name is unwieldy. By any standard, it is a major international organization, with responsibility for the disbursement of more than US$ 150 million in 1982 in support of agricultural research. It has some 40 members representing both the developed and the developing countries, several UN agencies, and various nongovernmental international development organizations. It is responsible for the broad support of 13 international research centres.

Yet, this organization has no constitution, no legal personality, no rules of procedure, and no system of voting — all its decisions are reached by consensus. It is not really an organization at all. It is a fragile web of contacts held together by the common belief among its members that it is not only necessary but viable. Perhaps the most remarkable thing about the CG is not that it exists but that it works and has worked well for more than a decade.

The CG was founded in 1971, but its origins can be traced to almost 30 years earlier. In 1942, the Rockefeller Foundation began a pioneering new program in collaboration with the Mexican government to improve agricultural production through applied research. The research program was aimed at solving the basic problems of the farmers in the production of the staple maize and wheat crops, and training Mexican researchers was a primary activity.

The approach paid off handsomely. The program helped Mexico become self-sufficient in grain production, encouraged the government to establish a national agricultural research institution (staffed by many of those who had been trained through the program), and won a Nobel Prize for the development of high-yielding wheat varieties. Inevitably, the activities broadened to include other countries of Latin America, then Asia, Africa, and the Middle East.

In the mid-1960s, by agreement with the Mexican government, the program became the International Maize and Wheat Improvement Centre, better known by its Spanish acronym, CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo). Some old hands at CIMMYT say that the second "M" was a printer's error and that the word "Mejoramiento," meaning improvement, was added at the last minute to avoid

embarrassment. In any event, the name stuck, as well it should, for such were the improvements brought by CIMMYT to the world's maize and wheat crops that in 1961 Rockefeller had joined forces with the Ford Foundation to establish a centre in Asia that would do the same thing for rice. This was IRRI, the International Rice Research Institute. With its headquarters in the Philippines, it was the first of a totally new type of research and training institution with an international staff and governing board.

In 1967, following the official "internationalization" of CIMMYT along lines similar to IRRI, the foundations established two more IARCs, as the international agricultural research centres were already being called. These were the International Institute of Tropical Agriculture (IITA) in Nigeria and the International Centre for Tropical Agriculture (CIAT — Centro Internacional de Agricultura Tropical) on the Colombian coast, both of which were to focus on the research needs of their particular agroclimatic zones. Further expansion was beyond the means of the two foundations, but the idea of linking these international centres and providing a mechanism for their continued support prompted a group of governments and international donor agencies to enter a series of discussions that led to the formation of the CGIAR.

That was in 1971, the same year that the International Development Research Centre began operations in Canada, and, from the start, there was close cooperation between the CG and IDRC. In fact, IDRC and the Canadian International Development Agency, the Canadian government's official aid arm, were both members of the first Consultative Group, which was sponsored by three UN bodies: the World Bank, the Food and Agriculture Organization, and the UN Development Programme.

The Consultative Group was conceived of as "nonorganizational." The only requirement for membership as a donor is the willingness to provide regular, substantial grants to support the international agricultural research system. Donors are not

CIMMYT's headquarters are in El Batan, Mexico.

IITA focuses on improvements for its agroclimatic zone.

required to support all the centres, however, and they channel funds to those that fit within their own priorities. In fact, only one donor supports all 13 of the centres that make up the network as it exists today. The Consultative Group also includes elected representation from all regions of the developing world.

The CG Secretariat is funded and housed by the World Bank; its role is to assist and advise the IARCs and the members of the Group, not to direct.

Complementing the CG Secretariat is the Technical Advisory Committee, TAC. This 13-member committee, made up of eminent scientists from both the developed and the developing countries, advises the Group on scientific and technical matters and conducts regular reviews of the centres' activities. It is served by its own small secretariat, which has four professional staff, is housed by FAO in Rome, and is funded by the three UN sponsors.

The purpose of the Consultative Group is to support the activities of the international agricultural research centres. Each centre has a director — normally a prominent scientist in that centre's area of specialization — and an international scientific staff. Each also has its own independent board of trustees, which sets general policies and priorities. Here, the similarity ends, for, despite their common allegiance, the centres are independent entities, shaped by the types of research they conduct, their locations, and, of course, the people who set their policies and administer them. They vary considerably in size, scope, and style, but there are essentially four types of IARC.

Some, like the West Africa Rice Development Association (WARDA) and the International Livestock Centre for Africa (ILCA), are regional rather than global in the scope of their operations. They were established to help meet pressing needs in that continent, where agricultural research facilities are extremely limited.

There are centres, like CIAT in Colombia's humid lowlands and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, that were established to conduct research on food crops in those agroclimatic zones that have been largely neglected by agricultural science in the past.

There are crop-specific centres, like CIMMYT, IRRI, and the International Potato Center (CIP) in Peru, that aim the main thrust of their research efforts at improving major food staple crops. Even among centres with similar orientations, there are differences in approach. CIMMYT, for example, has always concentrated most of its efforts on applied research, whereas at IRRI there has traditionally been a much stronger commitment to basic research.

Finally, there are three centres that are not active in agricultural research at all but are concerned with vital related issues such as economic and trade policy, the preserva-

Strengthening research capacity at the national level — the link between international and local programs — is the aim of the International Service for National Agricultural Research.

tion of plant genetic resources, and the development of agricultural research capacity at the national level in the developing countries. These three have been regarded with apprehension by some CG members who see them as a dilution of the original purpose of the Group. Such attitudes may be changing, however, particularly among the developing countries, where there is a keener appreciation, for example, of the need to ensure not just that there is enough food for each person but that each person gets enough.

In capsule form, the 13 institutions that make up the CG network today are:

- **CIAT: Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)**, Cali, Colombia, is concerned with the production of the food staples of the tropics of the western hemisphere, particularly beans, cassava, rice, and beef.
- **CIMMYT: Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Centre)**, El Batan, Mexico, supports research around the world on maize and wheat as well as other major cereals such as barley and triticale.
- **CIP: Centro Internacional de la Papa (International Potato Center)**, Lima, Peru, aims to improve the solanum potato and to develop varieties suitable for growing in many parts of the developing world, where it has great potential.
- **IBPGR: International Board for Plant Genetic Resources**, Rome, Italy, supports and promotes a network of international and national genetic resource centres to collect and preserve plant germ plasm.
- **ICARDA: International Center for Agricultural Research in the Dry Areas**, Beirut, Lebanon, and Aleppo, Syria, concentrates on rainfed agriculture in semi-arid regions of North Africa and West Asia, with emphasis on durum wheat, barley, faba beans, and lentils.
- **ICRISAT: International Crops Research Institute for the Semi-Arid Tropics**, Hyderabad, India, is concerned with improving the quantity and reliability of food production in semi-arid regions of Africa, Asia, Latin America, and the Middle East, with emphasis on sorghum, pearl millet, groundnuts, chick-peas, and pigeon peas.
- **IFPRI: International Food Policy Research Institute**, Washington, DC, USA, focuses on the sensitive economic and political issues surrounding food production, food distribution, and the international food trade.
- **IITA: International Institute of Tropical Agriculture**, Ibadan, Nigeria, concentrates on lowland tropical agriculture worldwide, with emphasis on roots and tubers, cereals, and grain legumes, as well as the improvement of traditional farming systems.
- **ILCA: International Livestock Centre for Africa**, Addis Ababa, Ethiopia, carries out research and development on improved livestock production and marketing systems for tropical Africa.
- **ILRAD: International Laboratory for Research on Animal Diseases**, Nairobi, Kenya, seeks controls for two major livestock diseases, trypanosomiasis and theileriosis, that limit livestock production in huge areas of Africa, Asia, Latin America, and the Middle East.
- **IRRI: International Rice Research Institute**, Los Baños, Philippines, the first of the international centres, continues to work on the improvement of tropical rice and rice-based cropping systems and related technologies.
- **ISNAR: International Service for National Agricultural Research**, The Hague, Netherlands, the youngest of the centres, responds to requests from developing countries for assistance in strengthening their national agricultural research programs.
- **WARDA: West Africa Rice Development Association**, Monrovia, Liberia, aims to promote self-sufficiency in rice for a 15-country region where rice is a staple food and where there is great potential for increased production.

Many formal and informal links exist between the centres. There are frequent exchanges of scientists so that work can proceed on projects more suited to one area than another. For instance, ICRISAT, which has the main responsibility for sorghum improvement, has a scientist based at CIMMYT working on the development of highland sorghum varieties for Central and South America. The centres often collaborate to present seminars, workshops, or training programs on a particular topic. And both the centre directors and the board chairpersons hold informal meetings at regular

intervals. Although they lack any official status, these meetings provide valuable opportunities for exchange of ideas and discussion of mutual problems and concerns.

In addition to scientific matters, the issues under discussion at such meetings might include possible modifications to the existing review process, which some see as excessive and unduly time-consuming; the need for improved communications at both scientific and administrative levels; the need for more, or fewer, centres; and, inevitably, money — finding the fairest way of dividing the financial pie and seeking a stronger voice for the centres in this process.

These meetings, and a host of other activities, draw the centres closer together. Independent though they are, they are also interdependent. As their research programs grow and broaden in scope, there is a natural tendency toward cooperation and coordination among the centres resulting from overlapping activities and interests. Additional strands are continually being added to the fragile web that is formed by the CG, the IARCs, and the national research programs, making it stronger and more flexible. It is still far from being a monolithic structure and remains as vulnerable to economic and political problems as does any other development institution.

The future of the IARCs is examined in the final chapter of this booklet. To put it in perspective, one needs a look at the past: a review of some of the accomplishments of the IARCs — not just the "breakthroughs," for they are rare in even the best of research programs, but also the essential, practical developments that have resulted in steady progress, helping to put more food and better food in the hands of the ordinary people of the Third World.

A high-yielding variety of rice in flower at IRRI.

Interactions

One of the primary reasons for the success of the IARCs has been that, from the outset, they have maintained a relatively narrow focus. Each concentrates on a few major staple crops or groups of crops, on particular agroecological zones, or on specific problems blocking the way to increased production.

This does not mean, however, that each centre works entirely apart from the others. Although one centre is usually designated as "lead institution" for a particular crop, there are often several centres involved in complementary research. Thus, IRRI has primary responsibility for research on rice. CIAT, however, also has a thriving rice research program as does IITA, and scientists from the centres work in close collaboration on the crops.

This chapter describes briefly some of the achievements of the centres in the major fields of research that account for the bulk of their programs. It is not intended to be a comprehensive review. More detailed and technical reports on the work of the IARCs over the years are available in their own extensive publications.

Every step in rice production is being studied.

Cereals The international agricultural research system began with IRRI and CIMMYT — they were the prototypes. The improvements they made were so spectacular that, within 10 years, almost one-third of Asia's rice was produced from IRRI's high-yielding varieties and almost half of the wheatland in the developing countries was planted to CIMMYT's wheats. From 1966 (when CIMMYT officially became an international centre) to 1979, India, the world's second most populous nation, tripled its wheat production and actually became a minor wheat exporter in the region.

There were good reasons for the early concentration on cereals, not the least being that they make up more than half the world's food supply. Wheat is the most important crop, followed by rice, maize, barley, and sorghum.

Although rice is generally regarded as an Asian crop (about 90% of the world's rice is produced in Asia), it is becoming more important in Latin America and is a staple in West Africa, which both produces and imports it.

The long-term goal of WARDA is to close the gap between production and consumption of rice in the region. The 15 member countries of the Association, which receives about one-third of its funding through the CG, annually consume about 3.5 million tonnes of rice. The region produces only a little more than 2 million tonnes, and consumption is growing faster than production.

With irrigation from the Senegal and Niger rivers, the semi-arid regions bordering the Sahel zone are capable of high rice yields, but the production problems are very different from those investigated by IRRI in, say, Thailand or the Philippines. Thus WARDA researchers draw on the experience and resources of IRRI, testing IRRI varieties, but they also seek to improve local rice collected from farmers all over West Africa. WARDA's coordinated seed-testing program has provided practical training for more than 150 research technicians.

In fact, training local staff is an essential part of the operation of all the IARCs. Thousands of scientific personnel at all levels have been trained at the centres, strengthening the national research programs of the developing countries immeasurably. For example, since WARDA was established in 1973, it has provided training for more than 600 scientists and technicians. These are the people who form the research networks that should eventually enable the region to achieve its goal of self-sufficiency in rice.

WARDA trials: improved rice varieties for the region.

IITA also has a rice program; its high-yielding varieties have been adopted by the government of Nigeria for its self-sufficiency program.

The demand for rice now extends to Latin America where high-yielding IRRI varieties were successfully introduced in the 1970s. Increased production has led to lower prices and greater popularity of the crop, particularly among the poor. If demand continues to increase at the present rate, production in the region will have to double in the next 20 years to keep pace.

The rice program at CIAT has concentrated on the improvement of irrigated rice, which accounts for about half the region's total rice production and appears to offer the greatest potential for rapid gains. The strategy has paid off. Working in collaboration with IRRI scientists, the CIAT researchers can claim much of the credit for a 60% increase in average yields throughout the region in the past dozen years.

The cereal crop more commonly associated with Latin America is maize (or corn), which is native to the region and is the traditional food staple from Mexico through the Andes. Maize is gaining in popularity, however, in South Asia, East and West Africa, and the Middle East. As the centre responsible for maize improvement, CIMMYT cooperates in research activities

at several centres. One example is at IITA in Nigeria where scientists have succeeded in developing an early maturing variety that will permit two harvests a year in some tropical regions and are working to develop high-yielding, disease-resistant varieties suited to the region. IITA supports an international maize-testing program across Africa that is helping national scientists to identify the best locally adapted varieties.

There are also close links between ICARDA and CIMMYT in research on wheat, barley, and the hybrid cereal triticale. Researchers at ICARDA have made substantial progress in developing advanced lines of barley with high-yield potential under drought conditions and on poor soils. Another promising line of research is the development of dual-purpose barleys, which first provide grazing and then recover to produce a grain harvest. This is of special importance in the dry areas where fodder for livestock is always at a premium. High yields and stability are the aims of ICARDA's wheat program, and a scientist from CIMMYT is posted at the centre to assist in efforts to adapt the Mexican varieties to the Middle East region.

Perhaps the most neglected of all the world's cereal crops until the establishment of the IARCs were the small grains, sorghum and the millets. These are the most important food crops of the semi-arid tropics, staples for perhaps 500 million people; yet sorghum yields in the developing countries average only about 20% of those obtained in North America where the

Maize selection at CIMMYT.

Stable yields under drought conditions offer the security subsistence farmers need.

grain is grown for cattle feed. Research conducted by ICRISAT in Asia, Africa, and Latin America is rapidly helping to correct this imbalance, however, as varieties with better resistance to diseases, pests, and drought are developed and adapted to local conditions.

Pearl millet, although not grown on anywhere near the same scale as sorghum, is an important traditional food crop in large areas of Africa and Asia. It is also hardy and a good source of cereal protein. As with sorghum, millet yields in the developing countries are usually well below their potential. Yet, ICRISAT has obtained spectacular yields of up to 3000 kg/ha on experimental plots, five times the average farmer's yield. The

researchers are working in close collaboration with national programs and the farmers themselves in efforts to test their high-yielding varieties and improved crop-management techniques under farmers' conditions.

Root crops Cassava is the third most important food crop in the tropical world and a major source of calories. This starchy native of the Americas grows well on poor quality, acidic soils — and in dry-matter production will outyield cereal crops under similar conditions by at least two to one. Researchers at CIAT believe cassava could eventually replace cereal grains (which are usually imported) as a basic source of food energy in many marginal agricultural areas. The world average cassava yield is about 10 t/ha; yet on experimental plots under ideal conditions it has been possible to obtain as much as 70 t/ha. The potential is enormous, and the establishment of a thriving worldwide cassava-research program is one of the CGIAR's major success stories.

Cassava is vegetatively propagated – part of the extensive selection program at CIAT.

Yams, cocoyams, and sweet potatoes are the other root crops for which IITA has major responsibility: low yields and poor storage quality are the major problems the researchers are working to overcome. Their efforts are producing impressive results — some IITA lines of sweet potatoes grown without the use of fertilizer have produced yields almost four times those of traditional varieties. Many of the IITA lines are also resistant to viruses and insects that in the past were largely responsible for holding down production. Another important step toward increased production has been the recent development of techniques for growing yams from seed rather than from tubers, which opens up entirely new prospects for breeding and selection.

Cocoyams in Cameroon: research on root crops is a priority for IITA.

The potato is another root crop that originated in the Americas and has spread to become a food staple in many parts of the world because it is rich in calories, protein, and essential vitamins. The potato does not adapt well to tropical conditions, however. In the tropics, it is susceptible to many diseases and

pests and tends to rot quickly in storage. One of the major thrusts of CIP research is, therefore, to breed lines of potatoes that can be grown successfully in these regions. Here, too, the development of improved techniques for the production of potatoes from seed is speeding up the breeding and propagation of improved varieties. Use of seed will also considerably reduce the cost of potato production, not just in the lowlands of Latin America but also in the Middle East, Africa, and Asia where CIP has regional programs.

CIP collaborates actively with regional postharvest and training centres where appropriate techniques for potato processing and storage are being developed and where scientists from the national research programs of many countries attend courses adapted from those originally developed at CIP headquarters in Peru.

Legumes Among the most important crops for people in developing countries are those of the legume family — peas and beans of many types. They are especially important in mixed cropping systems because of their ability to transfer nitrogen from the air to the plant. In effect, they provide their own fertilizer, the excess being available to associated crops or those that follow in a rotation. Rich in protein, food legumes are an essential part of the diet of 700 million people and complement cereal grains. Maize and beans, wheat and chick-peas, rice and soybeans are all traditional combinations that provide a bal-

Planting a nitrogen-fixing crop, such as cowpeas, with a nitrogen-demanding crop like maize substantially reduces fertilizer needs.

Washing and cooking potatoes in Peru: CIP has developed appropriate techniques for processing and storage.

anced diet. In the Middle East, legumes are known as "poor man's meat," and, precisely because they are the food of the poor, rather than a cash crop, many food legumes were generally neglected by agricultural science until the advent of the IARCs.

The neglect is rapidly being corrected. In the Middle East, a unique legume-research network established by ICARDA not only provides training for researchers from national programs throughout the region, but is also widening the agroclimatic

The Cassava Network

Cassava is produced in more than 80 countries, but just 5 — Brazil, India, Indonesia, Thailand, Zaire — produce two-thirds of the world's crop. Under ideal conditions on experimental plots, it can produce more energy per unit of land than any other food crop. It is the staple diet of some 300 million people, as well as an excellent animal feed and a valuable source of industrial starch.

Yet, this "wonder crop" was largely ignored by agricultural science until 1971 when the International Development Research Centre and the Canadian International Development Agency teamed up to support a major cassava-research program at CIAT. That program, which began as a one-person operation, has since grown into a network that links 40 countries and involves perhaps 500 people at any one time. Many hundreds more have been trained under the program.

The network's main goal is the development of high-yielding varieties adapted to a wide range of ecological conditions; thus, the most promising varieties are tested around the world. Some of the best produce more than 70 t/ha, up to seven times the average farm yield. Several processes for the use of cassava as animal feed have also been developed, including one that involves the use of cassava starch as a base for growing microbial protein to enrich animal feed.

In a sense, the program's major achievement has been the development of teams of researchers in the cassava-producing countries who can adapt the research results emerging from CIAT and IITA to their countries' needs. When the program began a dozen years ago, there was just a handful of scientists to be found who had any experience in cassava research. Today, there are hundreds; there is a

regular international exchange of information through workshops and CIAT's cassava information centre; and the program itself is now self-sustaining as more and more donors are getting involved in supporting the national programs.

range of major legumes. ICARDA and ICRISAT are also collaborating on chick-pea improvement in their respective regions and producing yields more than double those produced by the local farmers. Research at ICRISAT on pigeon peas has shown that yields of five times the world average are possible under experimental conditions, and the plant breeders believe they can improve the pea's performance even further.

Beans are a traditional staple in Latin America, too, but, in common with other parts of the world, the region has seen a drop in consumption in recent years. One reason is that diseases and pests make for an unreliable supply and widely fluctuating prices. The potential for increased bean production has been demonstrated at CIAT's experimental stations, however, where yields range from 2000 to 4000 kg/ha, compared with the average farmer's yield of only 600 kg/ha. The aim of CIAT's bean program is to develop varieties and simple techniques that will help farmers overcome the obstacles to production.

In Africa, the most important legume crop is the cowpea. Researchers at IITA have developed close to 100 lines with resistance to most common diseases, and the emphasis is now on overcoming the threat of insect pests such as aphids, thrips, and podborers, which are capable of completely destroying the cowpea crop over huge areas.

A relative newcomer to Africa, the soybean is not yet entirely at home there, although it is believed to have great

Research at ICARDA and ICRISAT has resulted in a doubling of chick-pea yields.

Pigeon peas in breeding experiments at ICRISAT.

potential as a protein producer in the tropics. IITA researchers are working to improve the plant's nitrogen-fixing ability without inoculation in African soils, one of the main characteristics that need improvement. Already, experimental crops at the Institute have yielded better than 3000 kg/ha, promising to outyield the traditional cowpea if such results can be reproduced under farm conditions.

Cropping systems Small- and medium-scale farmers rarely depend on a single crop for their livelihood. Most grow a

combination of crops, either together or in sequence. Some of these traditional cropping systems are quite efficient, but some are downright inefficient, even destructive, resulting in diminishing returns and depletion of the soil. Properly designed multiple-cropping systems, tailored to specific agroclimatic conditions, have the potential to increase farmers' overall yields, particularly when combined with fast-growing, high-yielding varieties such as those developed by the IARCs. Several of the centres are studying improved cropping systems as part of their research programs and working with national programs to encourage increased production through adoption of such systems.

In Asia, IRRI has established a 10-country network conducting research into rice-based cropping systems. In a region where the average farm size is less than 2 ha, the potential for small-scale farmers is striking. Planting dryland crops such as sorghum or maize after rice and making better use of rainfall and irrigation while retaining the best of the farmers' traditional methods have more than doubled farm incomes in some of the project areas.

In Africa, IITA researchers have found that cassava and maize grow well together. The fast-growing maize is not constrained seriously by the slower-paced cassava and helps to limit weed growth. After the main harvest, the canopy growth of the cassava plant helps protect the soil surface from rainfall erosion.

Cross-breeding cowpeas at IITA: the Institute has developed almost 100 disease-resistant lines.

Nitrogen-fixation analysis at IITA.

Intercropping systems: meeting specific agroclimatic conditions.

Another system under study at IITA — called alley cropping — involves planting food crops between rows of fast-growing leguminous shrubs that provide soil nitrogen, fodder or fuel, and organic matter to improve the soil. The system also limits weed growth and soil erosion.

The possibility of drought is always a concern of farmers in the semi-arid regions, and ICRISAT researchers are experimenting with various cereal–legume combinations to obtain maximum benefit from the limited rainfall in the region. Promising results have been obtained from pearl millet and

groundnut intercrops, with total production 20% higher than if the two crops were grown separately.

Latin American farmers use a remarkable variety of mixed-cropping systems, most of them based on the production of the region's staple grain, maize. Researchers at CIAT have obtained similar results to those of their colleagues in Africa when maize and cassava were combined. They also found that by adjusting plant densities it is possible to triple maize yields with only a minimal reduction in the cassava harvest. Tests with cassava and beans also showed satisfactory bean yields with no reduction in cassava output. The CIAT researchers are also seeking combinations of beans and maize that will maximize the yields from both of these staples and provide subsistence farmers with a better opportunity to earn some income from secondary crops without risking their livelihood.

Livestock The complete farming system includes not only crops, but a variety of livestock — poultry, pigs, goats, sheep, and cattle. It has been argued that animal production should not be encouraged because it is very often inefficient: to produce a kilo of grain-fed beef may take as much as seven times that amount of grain, and range cattle occupy huge areas of land, some of which might be producing food crops. There are more efficient ways of producing animal protein than by feeding grain to cattle, however, and grazing animals can make use of marginal land that serves no other agricultural purpose. Animals can also be used to convert other inedible agricultural by-products into milk, eggs, and meat and are a valuable source of draft power in the developing world. These are the areas of animal research with which the IARCs are largely concerned.

Sorghum after rice at IRRI: a promising combination for small farmers.

There are millions of hectares of savanna grassland in Africa that have enormous potential for production of beef and dairy cattle. But ranching is limited because of two insect pests that

The Making of a Research Network

Ten years ago, there were only two researchers working on grain legumes in the entire Middle East–North Africa region — a region where these legumes have served as dietary staples for millenia. One of ICARDA's first actions in its plan to establish a regional legume-research program was, therefore, to organize training courses for young scientists from the region.

These scientists are trained for 6 months in all the practical aspects of carrying out a legume-research program and then return to their home countries. Each takes home a valuable "souvenir" of the course — a supply of legume seed with which to carry out trials under local conditions with the help of occasional visits from ICARDA's staff. The results of these trials form part of a continuing exchange of seed and information with ICARDA.

This original approach to training has led to the development of a collaborative network of national legume-research programs that now stretches from Algeria to Bangladesh and from Turkey to Ethiopia. There are some 60 ICARDA-trained scientists at work in the national programs that make up this network, and their numbers are growing. Many of them return periodically to ICARDA for additional short courses or workshops — activities that strengthen both the national programs and the network. ICARDA plans to strengthen further these links in future by establishing a subcentre in Tunisia to serve the needs of the participating North African countries.

ICARDA's legume program, since its inception, has exemplified how the activities of national programs and international centres can complement each other. Each of the country programs

carry diseases fatal to the cattle herds: theileriosis, a tick-borne disease, of which east coast fever is the deadliest type; and trypanosomiasis, or sleeping sickness, that is transmitted by the tsetse fly. Researchers at ILCA and ILRAD are collaborating in a major effort to control these diseases to open up huge areas of unused land for animal production, not only in Africa but in parts of Asia and the Middle East.

Earlier researchers tried with some success, but at high cost, to control the disease carriers — the new thrust is concentrating on the parasites that actually cause the diseases and on the mechanisms that provide apparent immunity in some species, such as African Ndama cattle and some local breeds of sheep and goats. The researchers have recently succeeded in culturing trypanosomes in the laboratory, an important step toward finding out how these microorganisms survive in the host animals.

In tropical Latin America, there are also vast areas of savanna land that will not support productive agriculture because the soils are too acid and infertile — perhaps 50% of the region's land falls into this category. Scientists at CIAT are working to develop these lands into rich pastures that not only could increase production of milk and meat but could release for crop production other more fertile land that is currently used for grazing. The key to this ambitious scheme is the selection of forage legumes and grasses that can survive on the soils and the

operates independently, according to its own objectives and priorities. ICARDA provides improved breeding materials, advice, and assistance and receives, in return, data from multinational trials that enable its plant breeders to make further improvements.

The real winners in this collaborative exchange are the rural consumers of the region who stand to gain a reliable supply of a better product at a better price.

Much land that cannot sustain food crops is suitable pasture for livestock.

Trypanosomes undergo remarkable transformations that elude their hosts' ability to combat them.

establishment of a network of pasture-legumes research projects in countries throughout the Andean region.

More than 7000 plants have been collected from the wild, among them many that were previously considered weeds. Some of the most promising forage legumes are *Stylosanthes* spp., native Latin American plants that have been successfully adapted as forage crops in Australia. CIAT has organized workshops, training programs, and field trials to test these and other potentially valuable species. The research involves plant

breeders, soil scientists, and agronomists in a complex series of tests for nitrogen-fixing ability, disease resistance, soil deficiencies, nutrient value, and a host of other factors. The best are incorporated into low-cost pasture-improvement programs for testing throughout the region. Already, the results are promising, and the researchers believe the pasture improvement eventually will result in a 10-fold increase in productivity. The program also has great significance for other areas of the developing world where there are similar conditions.

Common factors Three of the centres have so far received no mention in this chapter. They are not, in fact, agricultural research centres in the same sense as the others. Rather than being concerned with specific crops or climatic zones, they are concerned with issues that affect all agriculture. The IBPGR was established to help conserve the world plant genetic diversity for future generations. IFPRI studies the economics and politics of food. And ISNAR's role is to strengthen national research capabilities. These are the common factors that affect the programs of all the commodity-oriented IARCs.

Much of the success of the IARCs has been based on genetic improvement of crops — achieved through the collection and careful storage of thousands of varieties of each species — and the painstaking selection of plants that have the required characteristics: disease resistance, drought tolerance, high yield, long or short stalks, abundant or limited foliage, rapid growth,

attle in Africa: trypanosomiasis and theileriosis are the major threats.

and so on. With time, patience, and sometimes a little good luck, the plant breeders can tailor plants to order, if the starting materials are available. And just as plants evolve, so do diseases and pests, so there will always be the need for more new varieties, more improvements.

Each of the IARCs that is the lead institution for a particular crop maintains a bank of thousands of varieties of that crop. At ICARDA there is a collection of more than 5000 faba bean lines. At ICRISAT there are 14 000 lines of pearl millet, 9000 lines of pigeon pea, and the world's most complete collection of

chick-pea germ plasm, with more than 12 000 lines "in the bank." The genetic resources unit (GRU) at IITA has a total of more than 20 000 specimens of cowpeas, maize, yams, sweet potatoes, and other crops. CIAT's GRU contains more than 30 000 bean varieties. CIMMYT has the largest collection of maize germ plasm in the world, with some 13 000 different types of maize from 50 countries in cold storage. At IRRI more than 60 000 genotypes of rice are to be found. These statistics should be reassuring to those who are concerned about genetic erosion — the gradual disappearance of many plant varieties from the wild.

The job of coordinating, supporting, encouraging, and reporting on all these activities at some 60 national and international research institutions is carried out by the IBPGR. The Board sets priorities, assigns responsibilities, and tries to ensure that there are neither gaps nor duplications of effort in the global conservation network. It also conducts a survey of genetic resources for specific crops and has begun producing directories of germ-plasm holdings. Every year the Board adds three or four more crops to its activities and, like the other IARCs, it is involved in training programs, providing courses in collection and conservation techniques for researchers from around the globe.

Ensuring everyone gets a share: IFPRI's mandate.

If the ultimate goal of the commodity-oriented IARCs is to enable the world's farmers to produce enough food for every-

Safeguarding germ-plasm resources is IBPGR's raison-d'être.

one, then IFPRI's role is to suggest policies to ensure that everyone gets a share of that food. This is an oversimplification, for the interactions between food supply and demand are extraordinarily complex, but it does illustrate why the network needs an institution to study and develop food policy. IFPRI studies the relationships between food production, consumption, and trade and how they are influenced by national and international policies. In short, it is concerned not just with how a new technique affects the production of a particular crop but also how the change impacts on the market and why.

Systems of Plenty

The new, high-yielding rice varieties developed by IRRI revolutionized rice farming in much of Asia, but, in the early 1970s, IRRI found that many farmers continued to grow only a single crop of rainfed rice. So IRRI set out to demonstrate the potential of rice-based cropping systems for the benefit of small-scale rice farmers. The objective was nothing less than "to explore the total food-production capability of the tropical rice farmer."

The research program began in a small way at IRRI, with a team of researchers studying the many types of interactions — both agricultural and nutritional — that must be understood before a new cropping system can be recommended to the farmers.

From the beginning, IRRI worked to develop research methods that would allow for a wide range of technical, socioeconomic, and agroclimatic factors. A series of workshops brought together cropping-systems researchers from throughout the region to exchange experiences and results. From this early research has grown a network of cropping-systems projects in a dozen Asian countries, many of them, like the original program, supported by research grants from the International Development Research Centre.

As is the case with most such programs, the backbone of the network is a strong training program. Young researchers come to IRRI from all over the region to study everything from plant breeding to rural sociology, with concentration on the principles of crop production, pest management, and agricultural economics. And they return home equipped to adapt and put into practice the best of both modern and traditional cropping-systems techniques.

One major area of research for IFPRI is food security. The Institute joined forces with CIMMYT in 1978 to sponsor a conference on the topic. This conference and earlier IFPRI studies on the subject were instrumental in convincing FAO and the World Food Council of the need for a "food financial facility" to help finance stable food supplies in the developing countries. This facility was subsequently established under the auspices of the International Monetary Fund.

The Institute's findings on the socioeconomic processes involved in agricultural development at all levels have an important bearing on priorities for research in the system. There is an increasing recognition, reflected in the research programs of the IARCs, that improved technology does not guarantee increased food production nor does an increase necessarily benefit those people who need it most. Thus, IFPRI works very closely with ISNAR, the newest of the CG-supported institutions.

At some point, the new technologies developed by the IARCs must be taken over and adapted by the national research programs if they are to be widely adopted by the farmers. In this respect, the role of the IARCs is to apply scientific principles to generate improved germ plasm, agronomic practices, and farming systems to be adapted by national programs.

The close relation between the IARCs and their national counterparts has, therefore, been a key to success. By the same token, lack of strong, capable national programs in some developing countries is a constraint to the spread of modern agriculture. ISNAR's main objective is to strengthen agricultural research capabilities in those countries and to help forge new links between the IARCs and national research systems.

IITA's germ-plasm collection: more than 20,000 specimens of cowpeas, maize, yams, sweet potatoes, and other crops.

Although it became fully operational only in 1981, ISNAR has already published, jointly with IFPRI, a review of Third World research systems, has conducted several national research program reviews, and has organized a series of seminars and workshops on research management in cooperation with other

IARCs. The cooperation strengthens the web of agricultural research, interweaving national, regional, and international programs and providing grounds for a reasonably optimistic view of the future for food. Unfortunately, there are also grounds for grave concern — the web is still fragile; the future of the IARCs is by no means clear.

Kenya's animal-production researchers work in close collaboration with ILRAD.

For the region's small farmers, taking part in the program often means an almost immediate increase in income — as much as 125% in a single year was reported from one project in Sri Lanka — as well as an improvement in diet and other benefits that stem from a small measure of prosperity.

Research results must be understood before they can be implemented by farmers.

Uncertain Futures

Tropical agricultural development has made huge strides in the past three decades. A large part of the credit for this progress must go to the international centres and to the far-sighted people who established them. The results obtained from the centres' problem-oriented, applied approach to the agricultural research needs of the developing countries have been nothing short of phenomenal. Yet, for the first time in its history, the international agricultural research system is faced with the real possibility of having to make serious cuts in its programs.

Like many other international institutions, the IARCs are suffering from the combined effects of worldwide inflation and recession. Budgets everywhere are tight, and there are some donors who believe that the activities funded by the Group should not be allowed to grow much larger, at least in the immediate future. There are some who say, in private at least, that the centres' activities should be cut — that whole programs, perhaps even entire centres, should be shut down.

Ironically, the system is a victim, not just of economic hard times but of its own success. In the early years of IRRI and CIMMYT, the major breakthroughs and spectacular results were achieved with such apparent ease that anyone unaware of what was really happening could be forgiven for assuming that the world's food problems would all be solved in a relatively short time. The news media coined the term "The Green Revolution," conjuring up visions of fertile fields, brimming food baskets, starvation averted in the tropical world almost as if at the flick of a switch. Unfortunately, the problem was not quite that simple.

The spectacular early results achieved by IRRI and CIMMYT came in the improvement of major established crops — rice and wheat. There already existed a vast amount of scientific knowledge concerning these two staples. The problem was to adapt that knowledge, by no means a simple task but one that yielded rapidly to the team-research approach. However, in these crops, the quantum jumps in yield have now been made. Further increases in yields are likely to come in much smaller increments.

In tackling the other major crops of the developing world, the IARCs were facing a different task. In many countries, the major staples such as sorghum, millet, cassava, yams, and the food legumes had for the most part been assigned low priority by the former colonial regimes for two main reasons: the colonials were focusing on crops such as cotton, coffee, cocoa, and tea to be exported to industrialized countries to realize healthy profits; and the populations in many regions were not so large and, hence, food crops were not generally in such short supply as they became later. (Where food crops were limited, research was often done — e.g., on maize, sorghum, and cassava in East Africa.) Also, as some countries made economic progress, during and after the colonial period, a demand for imported food grew, again reducing the emphasis on local food crops. When CIAT started its cassava program in 1970, it was able to identify no more than two dozen scientists around the world who had done work on the crop. Many of these were retired, or were close to retirement, and had not done any cassava research for more than 30 years.

The situation was similar for most of the other staple food crops of the tropics; therefore, it was unrealistic to expect dramatic results in a short time. Although the

costs and numbers of IARCs have grown rapidly (funding increased sixfold between 1972 and 1980), their apparent output has not increased at the same rate. In a sense, the centres are crippled by the unrealistic expectations created in the minds of some donors by the "great leaps forward" of the early years. Dr Don Plucknett, program officer with the CG Secretariat, points out that most research is incremental and time-consuming. "We are in a new era of agricultural research, and it is very exciting," he says. "But it is a mistake always to expect dramatic breakthroughs."

Dr Mujeeb Kazi, a research scientist in CIMMYT's wheat program, supports this view. He says: "In wheat, the quantum jump in yields has been made. Now what is important is to increase the areas in which it can be grown — to give it more adaptability." He is working on wide crosses between wheat and wild hill grasses in the hope of doing just that, but it is a slow process. "The first phase in plant improvement is breeding for desirable characteristics," Dr Mujeeb explains. "This is easy. Phase two is the creation of hybrids such as triticale. Phase three is when the plant breeder says 'I wish I could combine that with wheat' — the wide cross. But the success rate on wide crosses is less than 1%."

In the CG's own assessment, future successes are most likely to be achieved only by sustained and continuous effort. Many of the important food crops for small-scale farmers are grown in complex production systems. Consequently, it will be much more difficult in future to measure accurately the impact of new technologies than it was for rice, wheat, or maize, and progress will in all likelihood be slower.

The future of agricultural research is complicated by the fact that, while some countries have made important advances, thanks in part to the training and support available from the IARCs, others have lagged seriously. Spending on agricultural research in the developing countries showed an average annual growth of 10.5% during the 1970s and now exceeds the target of 0.5% of gross domestic product recommended by the 1974 World Food Conference. The number of agricultural scientists in the developing countries almost doubled during the decade, from about 18 500 to 34 000. There are now more agricultural scientists in the developing countries than in either the United States or in Western Europe. Far more are needed.

Dr Robert Havener, Director-General of CIMMYT, says: "One of the major tasks for the next 20 years is to continue building a pool of young scientists. There will be a continuing need for the IARCs, as training institutions, to bring along the young people to replace the present leaders in research. This is something we have to be very concerned about for the future."

Mujeeb Kazi: "What we are doing here is not just research for its own sake. The aim is to increase food production."

The need for researchers is emphasized by the continual shifting in the balance of food demand and food production among different regions of the world. The drift away from the countryside and changing socioeconomic conditions have created whole new sets of problems. Nigeria, for example, is experiencing new income from oil exports, rising industrialization, rapid growth of a middle class, dramatic changes in the diets of urban families, and a sharp increase in food imports. What all this amounts to is that research priorities are no longer as simple as they were in the 1960s, or even the 1970s. No matter how the problems and the priorities change, the need for research on food production will continue and is likely to increase.

The CG Secretariat warns of the dangers of "constraining the funding of the system too tightly." Inadequate funding, says a CG 5-year review published at the end

of 1981, would rapidly result in serious impairment of the work of the centres. The established centres need adequate funding to exploit new opportunities, to respond quickly to new ideas, and to develop new activities — all in addition to the continuation of their present research and training programs. The nature of the programs means that some must expand simply to maintain the progress already made. "Tightly constrained budgetting," says the review, "leads to inertia, a lack of flexibility, declining staff morale and failure to respond positively to the needs of the countries that the system is intended to serve."

The review adds, however, that the system "must remain dynamic and have the courage to discontinue activities as well as to support new ones." On one side in this debate are those who believe that it is better to cut off support for one or more centres altogether rather than to continue to remove limbs from an institution that has already undergone major surgery. On the other side are those who would limit the resources, and therefore the work, of the strong centres to provide more funds to the weaker ones.

That such a debate should exist at all is remarkable because the budget for all 13 centres is about $160 million — less than the research budget of the average large American university and just a fraction of the total world expenditure on agriculture research, which is about $4.5 billion. (Global expenditures on military research amount to almost $36 billion.)

The need to continue to strengthen the research capability of the developing countries is paramount, say many of the people most deeply involved. Dr Les Swindale, Director-General of ICRISAT, believes that to restrain the IARCs at this stage would be a terrible mistake. "I have never sensed so much optimism in India as there is this year," he says. "Productivity rates have traditionally been only about 1% or 2%. We are talking about bumping them up to around 4%. This is revolutionary — it has never been done on a consistent basis. The pearl millet increases are really spectacular. If we succeed with the new cultivars, this will be the next big success story to follow IRRI's rice." Nevertheless, he cautions against expecting instant results. "It still takes 20, 30, even 40 years to disperse a new technology throughout a country."

IRRI's Director-General, Dr M.S. Swaminathan, agrees with the long-term view. Beyond the 1980s, he sees biotechnology as being one of the major areas for research to bring about further improvement in food productivity. It is research that must begin now, he says, if it is to help increase and stabilize food production in the 1990s. "Food production in the 1980s will have to depend largely on the material already in the plant breeders' assembly line," he says, adding that the task for the immediate future is "the bridging of the gap between potential and actual yields in small farmers' fields by helping to eliminate the constraints."

The international agricultural research system is a fragile web. It is a web supported by contacts and commitments, ideas and ideals, inspiration and perspiration. Above all, it is a network of people — not just the scientists and administrators who staff the international centres, but the scientists, technicians, and the extension workers who make up the national programs. And beyond them, the farmers themselves, most of them managing as best they know how on a few hectares of land. Providing them with the know-how to do better, to grow more food, is the purpose of the entire structure. When they take the all-important step of trying new seeds or new planting systems, they are not aware that they are also joining a worldwide network.

Few small farmers in the Third World have ever heard of the CGIAR and its IARCs. Like farmers everywhere, they are concerned with results. If they can be shown that the new technology works, they will use it. Using new techniques like genetic engineering, scientists at the IARCs may eventually bring them plants the like of which they have never seen before. This is what Dr Mujeeb means as he surveys the odd-looking hybrids in his Mexican greenhouse and says: "What we are doing here is not just research for its own sake. The aim is to increase food production."