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Summary of

Consultative Group on International Agricultural Research

The CGIAR centers

Centro Internacional de Agricultura Tropical
(International Center of Tropical Agriculture)
Cali, Colombia

Centro Internacional de Mejoramiento de Maiz y Trigo
(International Maize and Wheat Improvement Center)
Mexico City, Mexico

Centro Internacional de la Papa
(International Potato Center)
Lima, Peru

International Board for Plant Genetic Resources
Rome, Italy

International Center for Agricultural Research in the Dry Areas
Aleppo, Syria

International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India

International Food Policy Research Institute
Washington, D.C., USA

International Institute of Tropical Agriculture
Ibadan, Nigeria

International Livestock Center for Africa
Addis Ababa, Ethiopia

International Laboratory for Research on Animal Diseases
Nairobi, Kenya

International Rice Research Institute
Manila, Philippines

International Service for National Agricultural Research
The Hague, Netherlands

West Africa Rice Development Association
Monrovia, Liberia

Foreword

It is appropriate that the CGIAR decided to commission a study of the effects that the centers it supports have had on agricultural research institutions and agricultural production in the Third World.

The external committee appointed to advise on the conduct of the study wishes to raise some issues on its own, and to acknowledge those whose wisdom, foresight, and hard work led to the initiation and successful conclusion of this study.

A word about the role of the advisory committee and the process is in order. Its members were broadly drawn from diverse disciplines and institutions, with varied national backgrounds. The committee functioned as a support group to the director, Jock Anderson, in the design and organization of the study and as a reviewing body at intermediate and final stages. The process worked well—the advisory committee is pleased with and fully endorses the product. The committee was impressed with the high degree of professionalism and the organizational skills of the director, and has the highest regard for the manner in which he interacted with the committee, assembled his team, and carried out this difficult charge. The director enjoyed especially strong support in executing the project from Robert Herdt who carried staff responsibility for the study within the CG Secretariat and also interacted most successfully with the committee.

The CGIAR was launched shortly after the first days of the "green revolution" when semi-dwarf wheat and rice varieties, developed by the first two centers, were spreading rapidly and when the world's attention was focused on the food crisis in Asia. The descendants of these varieties, developed cooperatively with the national programs, remain the largest contribution of the system, and that is large indeed. There are indications that the centers' work on other commodities is also beginning to pay off. Center-related maize varieties have spread to over 6 million hectares in developing countries; new bean varieties are spreading, improved potato clones are being used, and new cowpeas are being grown by African farmers. The system has made a major

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contribution through training to increasing the capacity of developing countries to conduct research. These contributions alone demonstrate the enormous utility of a coordinated world system of agricultural research and training.

The wheat and rice breakthroughs were based on a backlog of basic knowledge in the plant sciences that is not so readily applied to dryland crops, which are particularly important in parts of Africa, the center of today's food crisis. Wheat and paddy rice are grown on large, rather homogeneous areas while sorghum, millet, cassava, and the various food legumes are dispersed across a wide diversity of ecosystems.

The world's attention is now focused on the profound problem of food in Africa. The causes are manifold: drought, strife, population growth, political imperatives, policy decisions, and world economic conditions all contribute. The CGIAR centers are devoting a substantial part of their resources to these problems: four centers are located in Sub-Saharan Africa, as is the sub-center of another. The impact of their work has thus far been modest, especially compared with the impact of the semi-dwarf wheat and rice varieties. This is to be expected in view of the scientific and technical difficulties let alone the other factors responsible for famine.

The committee believes that, in the years ahead, the conditions that led to the initial successes of the CGIAR system will be changing. Many developing countries have organized national research systems (to a considerable extent spurred by the success of the international centers) with the ability to conduct adaptive research. More will do so in the years ahead. It will require bold steps to shift the research focus and the structures of many of the centers from classical adaptive research on specific varieties to the supply of new methods and new breeding materials, many based on the rapidly developing methods of genetic engineering and biotechnology. This involves a changing emphasis from highly applied to more basic research. It also involves enhanced links between the centers and the forefront national laboratories in molecular genetics. These links will be effective only if the centers have staff members trained in these new techniques.

Agricultural science in the 1980s is in a state of rapid transition. Genetic engineering and other tools of biotechnology promise to greatly increase the potential gains from investment in research. Significant advances in molecular genetics, relevant to the work of the centers, have involved discoveries of ways in which the genetic material can be manipulated in animals, plants, and microorganisms. Since a great deal of the work of the centers concerns the exploitation of germplasm in plant breeding, they must take the earliest possible advantage of the new technologies. This is especially important since the time required to bring new knowledge into practice is now much shorter, and entirely novel crop characteristics can be created. The CGIAR centers will have to pursue these new avenues of research in addition to or in place of their current activities if they are to expeditiously meet their primary responsibilities to alleviate hunger in the Third World.

It was understandable to address the problem of food production on an emergency basis at a time when millions of people in Asia and elsewhere were faced with almost certain prospects of undernourishment and hunger. These dangers still exist not only for people in large parts of Africa but among the poorer strata of society everywhere. Nevertheless, it is important that problems of food supply are also tackled bearing in mind the longer-term perspective of preserving vital ecological balance and protecting the environment. Short-term gains which jeopardize longer-term goals cannot have a place in an integrated strategy for meeting basic needs worldwide on a sustainable basis.

It has been recognized for decades that there is a need for the development of appropriate technologies that might permit sustainable use of lands subjected to slash-and-burn systems and the other forest removal techniques. Population pressures and numerous other factors have been dramatically increasing the intensity of deterioration of tropical environments. The extreme situation is posed by those millions of small-scale and marginal farmers trapped on degraded lands and lacking new areas or productive lands to which to move.

The international centers and those that sponsor, guide, and finance the centers do have a profound interest in the development of systems that can contribute to alleviation of pressures on remaining tropical forests and fragile environments, permitting sustainable agriculture and animal husbandry on cleared lands (thereby reducing further destruction). Consideration must be given to appropriate arrangements for research to help national institutions to develop management methods, technologies, and policies for sustainable agriculture, animal husbandry, plantation forestry or agroforestry, and rehabilitation of degraded tropical areas.

A case can be made that research should not focus exclusively on food crops. The principle of division of labor and mutually beneficial trade applies as much to agriculture as to anything else, and it may make sense for farmers in many poor regions to specialize in commercial crops rather than in food production so as to maximize their incomes as well as the chances of feeding the entire population in the region on an economical basis. The role of international centers, vis-a-vis national centers in research on commercial crops needs to be worked out in order to meet the needs of poor farmers, bearing in mind the crops they are best suited to produce.

Finally, it cannot be overstated that the work of the centers is of benefit not just to the developing countries. It is an aspect of the growing interdependence of all nations that anything which contributes to the well-being of large numbers of people anywhere tends also to benefit the rest of the world. This is perhaps more true of scientific and technological progress than anything else.

Frank Press

Chairman, Advisory Committee

In brief: Conclusions from the study

The international agricultural research centers were conceived as a mechanism that could draw upon the global stock of knowledge, scientific talent, and plant material to address some of the urgent needs of developing countries. By the 1960s, when the first centers were established, it had become clear that growth in agricultural productivity could not be achieved simply by transferring technology to developing countries. Progress could only result from the generation and diffusion of technologies relevant to local ecologies and economies.

The early work with national research programs emphasized training and germplasm collection and improvement. As the center system has evolved and new centers have been created, attention has spread to a wider range of environmental conditions, more crops and livestock species, and more soil and pest complexes. The importance of adaptation of new technologies to specific local conditions has grown. As the focus has shifted, the 13 centers have increasingly established close working relations with their national counterparts. The trend toward closer ties has been facilitated by the rising scientific quality of national programs, which is the result of larger national budgets for research and, in part, assistance and training provided by the centers.

The study of the 13 international centers attempted to assess the changes that had been accomplished through the existence of the centers and to document the perceptions that researchers in developing countries hold about the centers' work. The major conclusions of the study:

1. The system of agricultural research centers that are supported by the CGIAR provides critical ingredients—both material and intellectual—that have helped many developing countries to reap high returns from technological investigation. The centers have provided a vehicle for transferring innovations based on crop germplasm from country to country along with the knowledge of how to adapt such innovations to local conditions and how to achieve further advances. **If the system of centers did not exist, something very much like it would have to be invented.**

2. Most of the tangible economic benefits of the CGIAR system trace to the modern wheat and rice varieties developed by national programs in part from genetic materials provided by the centers. Modern varieties cover 115 million hectares or half the total plantings of wheat and rice in the developing world. Since they were first adopted by farmers in the mid-1960s, center-related wheat and rice varieties have spread rapidly in most developing countries where the crops are grown. They do best with irrigation, but as researchers produce more specifically adapted varieties, substantial areas of rainfed land are being affected. These varieties annually yield about 50 million tons more than the old varieties would have produced, enough to provide food grain for about 500 million people.

3. Varieties of maize and field beans derived from genetic material provided by the centers are beginning to have a measurable impact on food production. Developing countries have released over 200 center-related maize varieties, and over 6 million hectares are planted to them. Nearly 100 center-related bean varieties have been released. About half the field beans planted in Argentina, Costa Rica, Cuba, and Guatemala are center-related varieties.

Over 250 center-related varieties of sorghum, potato, cassava, chickpea, cowpea, pasture species, pearl millet, pigeonpea, and durum wheat have been named by national authorities. The area planted to them is still small because many of these varieties have been released only since 1980.

4. The benefits from adopting modern varieties have been remarkably evenly distributed among farmers differing in size of holding and tenure status. A major part of the gain from the new technology has accrued to food consumers both rural and urban. Food makes up 60 percent or more of the expenditures of the poorest people in most developing countries. Consequently, reductions in the real price of rice and wheat, such as those brought about by technological

change, favor the poor more than the affluent, who spend a smaller share of their incomes on food. But in terms of the overall distribution of real incomes, these improvements are marginal. Technological advance, while vital for the development of agriculture and the economy, is a poor instrument for redistributing wealth.

5. Agricultural research is a time-consuming and uncertain undertaking. Despite the record of high returns to investment in research, few small countries can afford to mount productive research programs on all fronts, particularly if their agriculture is diverse. For these countries in particular, **the centers' role as a provider of biological material and scientific resources, will continue to be required well into the future.** In fact, some national scientists have urged that it expand to embrace more crops and livestock species. Furthermore, in the difficult and resource-poor institutional environments that prevail in many countries, the kind of assistance provided by the centers is very valuable to national programs.

6. The type of contribution made by the centers is related to the stage of development and the capacity of the national system. Countries with thin research capacity benefit by directly adopting technologies produced by the centers; countries with moderate capacity carry out some adaptive research on centers' products to produce their own technologies; while countries with strong research capacity are mostly interested in the ability of the international centers to deliver research products specific to some of their individual problems.

7. In their chief enterprise, the improvement of germplasm, the centers are responsive and fair in dealing with their collaborators and their often conflicting priorities. **Plant genetic collection and conservation by developing countries have been greatly stimulated by the IBPGR and other CGIAR centers.** Genebanks now hold substantial collections of most major crops. During the past 10 years, seeds of 138 crop species have been collected in 88 countries in over 300 missions promoted and partly financed by IBPGR. The materials collected have been placed in the genebanks of 450 organizations, more than half of which are in the developing world. But the centers may be underutilizing the wild relatives of some crops. They also could be more active in exploring the uncertain promise of biotechnology for unlocking the potential of these collections.

8. The centers have raised the capabilities of thousands of research personnel in developing countries through their training programs. Even courses lasting only a few weeks are well regarded by the participants and seem effective in enhancing research productivity.

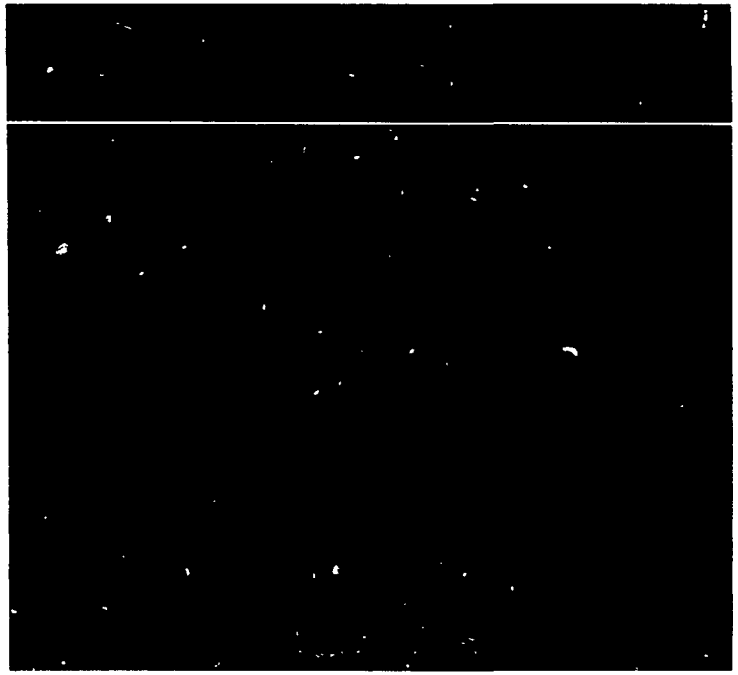
9. The crops, livestock species, ecologies, and issues that form the individual mandates of the centers differ markedly. **For many centers, the challenges that they face are so perplexing and the constraints imposed by poor infrastructure, depressed commodity prices, lack of agricultural inputs, and low levels of knowledge are so difficult that it is too soon to expect impressive returns from their work.**

10. The centers' emphasis on the human aspects of technological advances has grown as interest in farming systems research has spread. Nonetheless important areas such as the problems of female farmers in male-dominated societies and the limited presence of women in research organizations have hardly been touched.

11. The centers' research on policy issues is helping national authorities to correct faulty perceptions and to argue against unwise decisions affecting food production and consumption. But considering the magnitude of the problems, the centers' efforts can address only a fraction of the vital questions. The political as well as economic aspects of policy making must be confronted by the countries themselves in order to accelerate agricultural advances.

12. The collaborative arrangements between the centers and research workers in developing countries have been demonstrably productive. One of the most appreciated activities of the centers is the effort that they make to overcome the barriers that often isolate researchers in developing countries from the global knowledge system and the international scientific community.

New varieties: Number of center-related varieties released by national authorities in developing countries through 1983.



Partners in Research

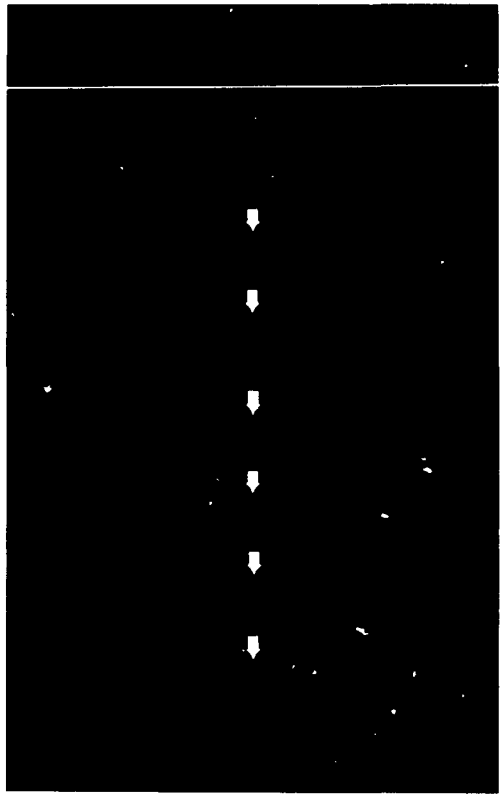
Better plants

Wheat and rice. The rapid spread of modern varieties of rice and wheat attests to the power of the research engine formed by the joined efforts of the international centers and national research agencies. These varieties, mostly released since 1965, handsomely rewarded farmers who invested extra effort in good management.

Multitudes of farmers throughout the world have exploited the genetic potential of the new varieties. They plant modern wheat varieties on 47 million hectares or nearly 50 percent of the wheat area of developing countries. Modern rice varieties cover 70 million hectares or about 55 percent of the rice land in developing countries. China alone accounts for about 32 million hectares of the new rices. (Breeders there developed short, fertilizer-responsive varieties without IRRI assistance in the 1960s, but in the 1970s they began extensive use of IRRI-developed varieties for their newest hybrid rices.)

For most adopting farmers, the new varieties typically outyield the old varieties by 400 to 500 kilograms per hectare. Thus, worldwide, they annually provide over 50 million tons of additional food. That is a quantity about equal to the annual grain consumption of a half billion people.

Other crops. Developing nations have released over 200 maize varieties developed from genetic materials supplied by the centers. Half of these varieties are grown in Latin America, with the rest

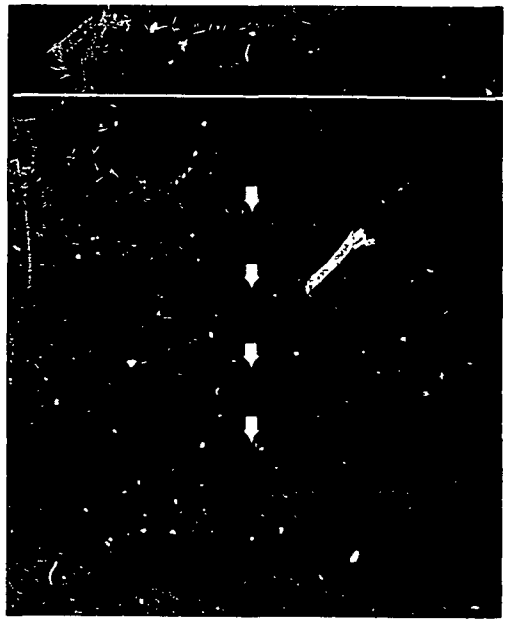


about equally divided between Africa and Asia. The new varieties cover 6 million hectares in over 15 countries. CIMMYT's Tuxpeño group of maize lines has been notable for disease resistance. The incorporation of resistance to streak virus in some new maizes by IITA gives them special promise for Africa.

More than 90 CIAT-related varieties of field beans have been released by authorities in 23 developing countries since 1981. Little information on their spread has accumulated so far, but three recent studies

have shown that 35 to 65 percent of the bean areas in Argentina, Cuba, Costa Rica, and Guatemala are planted to the new varieties.

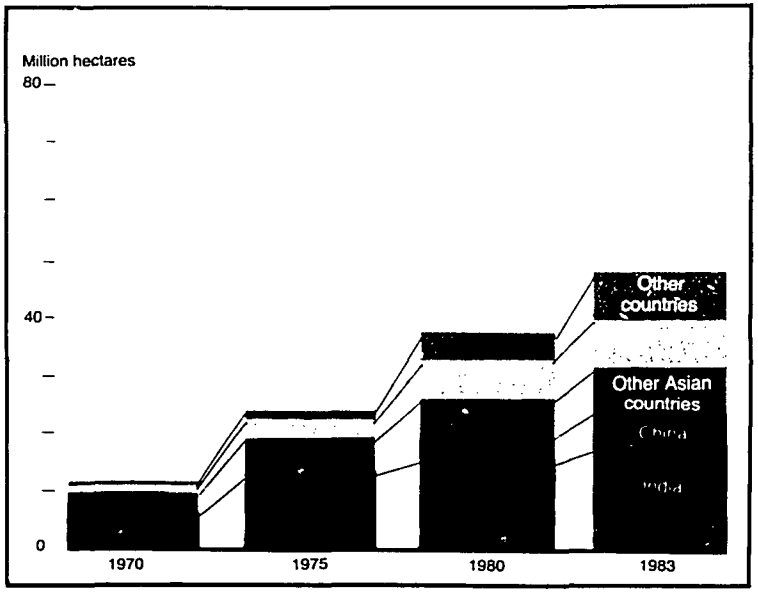
Over 60 center-related cassava varieties have been released by 16 countries in Africa, Asia, and Latin America; over 30 sorghum varieties and eight pearl millet varieties derived from ICRISAT's research have been released in more than a dozen countries; 29 varieties of cowpeas derived from IITA's research are known to have been named by national authorities, half in African countries; over 40 varieties of durum wheat related to CIMMYT and ICARDA research have been released, mainly in the Middle East and North Africa where durum is a principal staple; 23 countries have released over 60 potato varieties obtained and tested with CIP's assistance. Varieties of chickpeas, pigeonpeas, barley, triticale, and pasture and forage crops derived from center efforts are also being released and are beginning to reach farmers.



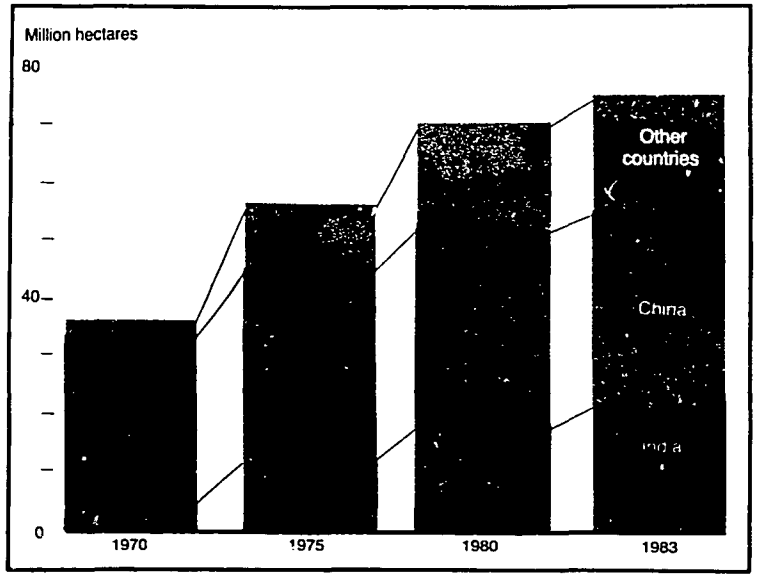
The plant improvement process. The process of plant improvement is laborious and, inevitably, time-consuming. The initial steps in the development of new crop varieties are to collect and characterize germplasm—farmers' varieties, wild strains, and related species—and to assess farmers' needs in order to set breeding priorities. From data on the genetic materials and from examination of growing plants, the breeders choose, as parents for crosses, plants that have characteristics that they hope to combine in offspring. After the first cross, the progeny exhibit widely divergent characteristics as a result of genetic segregation. Breeders choose progeny with desirable characteristics and plant their seeds to form the next generation, or they may use selected plants to make additional crosses. By deliberately exposing the plants to high populations of insect pests, to high incidence of disease pathogens, or to other stresses, the breeder can cull inferior plants—the so-called screening process.

After five to seven generations (many breeders grow two generations a year), lines that have survived intense environmental stresses and the breeder's unforgiving eye undergo preliminary yield testing. The lines are usually grown at several locations to get data on their reactions to different soils, climatic patterns, and complexes of diseases and insects. The international centers with crop improve-

Land in new wheats: Estimated area planted to modern wheat varieties in developing countries.



Land in new rices: Estimated area planted to modern rice varieties in developing countries.



ment programs may carry out all the above steps, as do some developing countries that have large research capacity. Centers normally enter their most promising materials into international tests, or nurseries, that are distributed to national breeders who request them.

National researchers who have responsibilities for developing finished varieties may evaluate lines or varieties from international nurseries for their domestic suitability, or they may produce their own crosses using germplasm from domestic and international sources. The former approach involves somewhat fewer steps within the country, but still takes additional time.

Whether at a center or in a national program, the minimum time between beginning the process and the identification of a promising line is 6 to 14 years. Countries that rely on breeding done at centers typically require an additional 3 to 6 years for in-country testing and release. Seed multiplication must then follow.

Improved farming methods

Research on improved methods and materials for production is an important part of the work of the centers. Diverse products result: new machines, procedures for better management of experiment stations, and methods of producing disease-free planting material are some examples. Only a few technologies have reached widespread use among farmers so far.

Crop intensification. Most traditional varieties are sensitive to daylength,

The work of the centers

Diversity. The 13 centers that constitute the CGIAR system were established at different times by different sponsors with different objectives. IRRI, CIMMYT, CIAT, and IITA were in operation before the CGIAR existed.

The centers are a heterogeneous group. They work on different commodities and problems and, in many instances, serve different regions. Eight of the centers are heavily involved in crop improvement work. Four centers focus on a particular region. Nine operate some form of farming systems program. Two are devoted to livestock research and another two include research on pasture or forage crops in their activities. Three have no laboratories or experimental fields because their work is directed to people and policies.

All centers are problem-focused. Thus to find solutions quickly, most use a multidisciplinary approach.

The centers are international in more ways than merely working with many nations. Their staff members are recruited worldwide. The governing boards are composed of men and women from donor countries and from countries in which the work of a center is important, though with a few exceptions, the members of the boards serve in their individual capacities, rather than as representatives of their countries.

Staff members of the centers are located in 36 countries other than the 13 in which the centers have their headquarters.

In staffing the centers, a guiding principle has been to hire the best qualified professionals that can be found and to provide them with high quality facilities and adequate support and supplies to carry out first-class scientific work.

Each center determines its own program. The Technical Advisory Committee of the CGIAR periodically examines the programs of the centers and comments on the research priorities being pursued, but it has no direct control over the centers. Since they are also independent of governments, the centers operate relatively unfettered by externally imposed red tape.

Objectives. Most scientific activities at the centers can be classified as applied research. Basic research is rarely undertaken except where it is necessary for the solution of a specific problem. Crop improvement, in its various aspects, occupies the majority of the senior staff. About 15 to 30 percent are engaged in other applied research activities such as agronomy, economics, engineering, farming systems, and animal nutrition.

Cereals that provide 60 percent of the food energy consumed by people in developing countries dominate the research activities of the CGIAR centers. The centers also conduct research on the most significant root and tuber crops. In addition, livestock problems in Africa are addressed by two centers. Overall, the foods that contribute three fourths of the food energy and three fourths of the protein of diets in developing countries are under investigation by the centers.

Regional emphasis. Of the centers' staff members who are posted outside their headquarters, about 40 percent are in Sub-Saharan Africa, about 25 percent in Latin America,

Participants in centers training programs, 1962-83.

	Formal	*Degree*	*Individualized*	*Postdoctoral*	*Total*
Sub-Saharan Africa	6248	308	344	106	7006
Middle East & North Africa	807	47	71	7	932
Asia	3453	607	518	282	4860
Latin America	2143	246	1427	77	3893
Developed nations	2155	218	155	210	2738
Total	14806	1426	2515	682	19429

and 20 percent in Asia. In terms of crops, about 40 percent of the investment in rice research is directed toward problems in Asia, about 50 percent of the research investment in roots and tubers is directed toward Africa, and 60 percent of the research investment in food legumes is directed toward West Africa, North Africa, the Middle East, and India.

Links with national programs. The centers and the national programs are linked through a variety of means: training, research networks, flows of information, and meetings and conferences. Formal training courses last from 2 weeks to 6 months and usually focus on specific research skills. Close ties are often formed between researchers in the centers and national programs through thesis-related research, individualized training programs, and post-doctoral appointments at the centers. At any time, there are about 350 candidates for master's and doctoral degrees who are conducting their thesis research at the centers.

Research networks take many forms: some involve germplasm exchange, others are organized around specific research problems. The centers make library services available to national researchers along with a broad range of specialized publications produced by the centers. For some researchers in national programs, the centers are their primary source of scientific information.

Information programs. Information development and distribution is a high priority of the centers. Each center produces publications and other information materials aimed principally at researchers and policy makers in national and regional programs. Other important audiences include extension program personnel, students of agriculture, and donors. To date, an estimated 10,000 titles have been produced on subjects covering a dozen commodities and two dozen scientific disciplines.

The centers' annual reports serve the function of communicating research results to national programs, while their research highlights are aimed more at helping policy makers and donors keep abreast of centers' activities. A variety of specialized publications concentrate on a specific discipline or geographic area or expand on a highly technical subject. Included are monographs based on completed research projects, bibliographies derived from center databases, and proceedings of international workshops and symposia. The centers also publish about 30 newsletters. Some centers routinely produce publications in Spanish or French, as well as English.

Growth of the system. The CGIAR was launched in 1971 when there were four centers already in existence whose budgets totaled $18 million. By 1984, the 13 centers in the CGIAR had budgets totaling nearly $180 million. During that period, the number of donors contributing to the system rose from 16 to 35, including several developing countries. Compared with changes in official development assistance for agriculture during the past 15 years, the growth of expenditures on the centers has been rapid. But the total budget of the CGIAR system is a small fraction of all expenditures on agricultural research by developing countries.

Development funding: Official development assistance to developing countries, national agricultural research expenditures, and expenditures of the CGIAR centers.

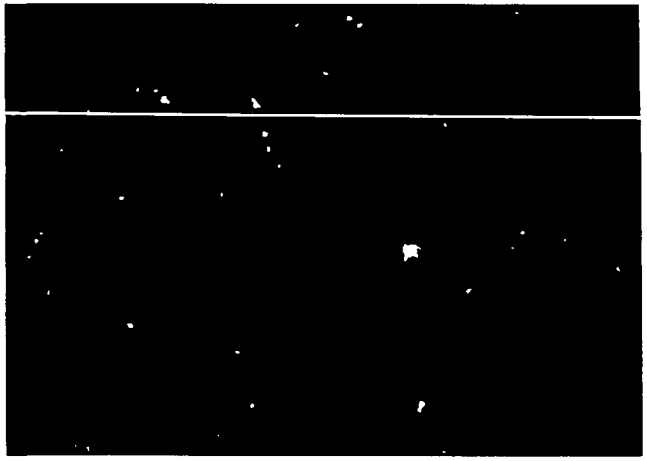
	1970	1980	1982
	($ millions, 1981 constant dollars)		
Official development assistance	21,300	36,200	35,000
Bilateral	18,500	28,600	27,400
Multilateral	2,800	7,600	7,600
Grants by PVOs	2,200	2,200	2,400
National agricultural research, world	5,400	7,400	n.a.
North America, Oceania, W. Europe	2,400	3,200	n.a.
USSR and E. Europe	1,300	1,500	n.a.
Developing countries	1,700	2,700	n.a.
CGIAR expenditures	20	140	140

which means that they do not flower until some critical number of hours of daylight occurs. Thus planting traditional varieties in the "off-season" makes little sense because grain will not set until the time of year when the critical daylength occurs. Most modern wheat and rice varieties, however, are daylength-insensitive—the length of the period from planting to harvest is rather fixed regardless of season. And the newer varieties of wheat and rice have been bred to mature even more rapidly without sacrificing yield.

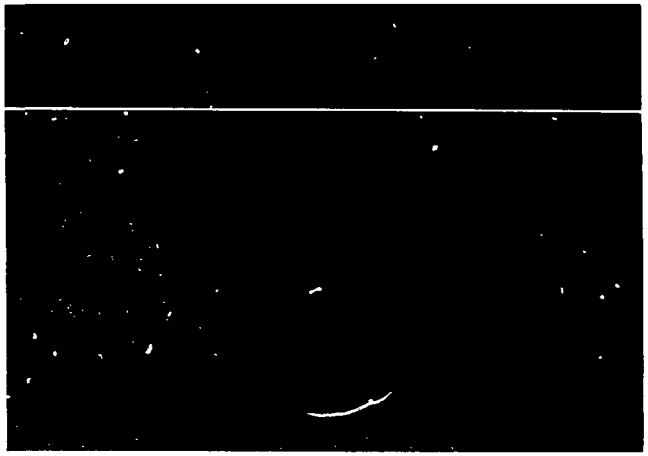
Fast-maturing varieties and improved practices have enabled some farmers to squeeze in an extra crop during the year. For instance, the introduction of modern wheat varieties in Bangladesh permitted wheat to be planted in the winter when most farmers have too little water to grow rice. Unlike traditional wheat varieties, the new wheats flower and ripen during the short days of winter, so they can be harvested before the next season for planting rice arrives.

Bangladesh now grows half a million hectares of wheat, nearly all in modern varieties, which is 10 times the area harvested before the advent of modern varieties. This remarkable increase was achieved without abandoning other crops. During the 1970s, double- and triple-cropped land rose by 1.9 million hectares. Multiple-cropped land fell in 1971 and 1972, following the uncertainties of the liberation movement. Thereafter, as conditions stabilized, it increased to new, higher levels. Although expansion of irrigation promotes multiple cropping, in Bangladesh over 60 percent of the new wheat area lacks irrigation—the crop

Wheat: The adoption of modern varieties.



Rice: The adoption of modern varieties.



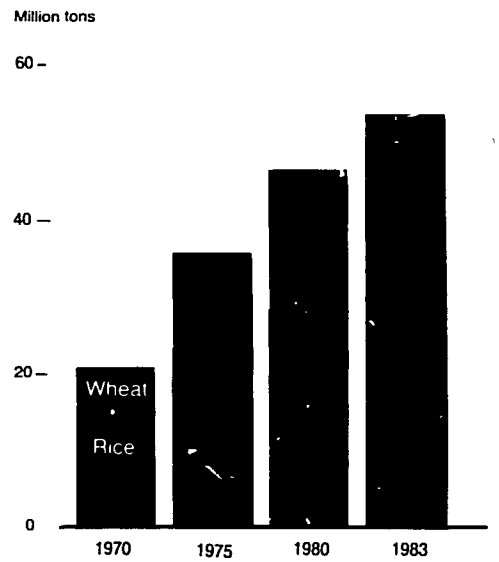
grows on residual soil moisture and water from the occasional winter rains.

Cassava cultivation. Cuban cassava production has expanded by a factor of 15 during the past decade, chiefly owing to new methods for cassava production developed by Cuban agronomists working with CIAT and popularly known as the "Colombian system."

Since cassava is a relatively new crop for them, Cuban farmers have managed it like sugarcane, planting short stakes horizontally in furrows and irrigating heavily. With the help of CIAT, Cuban researchers evaluated the cassava varieties being grown by farmers and selected the best ones for propagation and diffusion. They also developed improved practices: cutting the planting stakes longer and chemically treating them to suppress bacterial blight, thoroughly preparing the field with higher ridges than those customarily used for sugarcane, placing the planting stakes vertically at the top of the ridges, controlling weeds in time, and irrigating moderately. On state farms, which have 10,000 hectares of cassava, or a fifth of the nation's cassava land, yields have climbed to 20 tons a hectare from 7 tons a hectare.

Threshers. Commercially produced rice threshers manufactured from designs developed by IRRI have significantly reduced costs for many farmers in the Philippines and Thailand, and thus promoted increases in output. In the Philippines, the threshers are replacing manual threshing and foot treading, which may have disrupted employment opportunities, especially for female threshers. Although the per ton cost of threshing remains much the same, threshers have reduced losses of grain during threshing. In contrast, in Thailand, where the IRRI threshers are replacing tractor treading or driving repeatedly over the grain with tractors, farmers suffer slightly higher threshing losses, but the costs are lower.

More food: Estimated additional food-grain produced by modern wheat and rice varieties.



Seed potato storage. CIP researchers have promoted the evaluation and adoption of diffused light storage for seed potatoes in many developing countries. Although farmers in many areas conventionally store seed potatoes in the dark, storage in diffused natural light slows sprout elongation, increases sprout numbers, and reduces storage losses. Farmers

get higher yields because of the greater sprout vigor of the seed potatoes, and they benefit from being able to store seed potatoes longer, so they can time their planting to place the harvest in a period when the markets are less likely to be oversupplied with potatoes.

This storage system is being used extensively in Peru, Colombia, the Philippines, and Sri Lanka and has been introduced in other countries. On-farm trials in Peru, Colombia, and the Philippines showed that diffused light storage of seed potatoes resulted in yield gains of 8 to 20 percent. Trials in Sri Lanka showed yield increases of 80 to 133 percent. If a 20-percent yield increase occurred on 10 percent of the potato land in the countries where CIP is actively promoting the technology, the result would be an additional 1 million tons of potatoes worth about $100 million a year.

Deep Vertisol technology. ICRISAT has developed improved production practices for deep Vertisol soils in the higher rainfall areas of semi-arid India. The broadbed-and-furrow system involves land leveling and shaping, construction of field and community drains, tillage following the harvest of the winter crop, use of graded beds and furrows, dry seeding of modern varieties before the monsoon, moderate application of fertilizer, and timely plant protection. Most of the practices are best carried out with a bullock-drawn wheeled tool carrier, which would be a substantial expense for poor farmers. Yet, trials conducted in several states of India have shown that the composite technology is profitable. By 1983 the broadbed-and-furrow system was in use on about 4000 hectares, mostly on farms operated by state governments. The technology seems well-suited for up to 5 million hectares.

Azolla. Farmers in China and Vietnam cultivate azolla, an aquatic fern, in rice paddies as a green manure crop. It improves soil fertility because it provides a home for nitrogen-fixing micro-organisms. However, azolla works best on soils that have high levels of available phosphorus and where careful water management is possible.

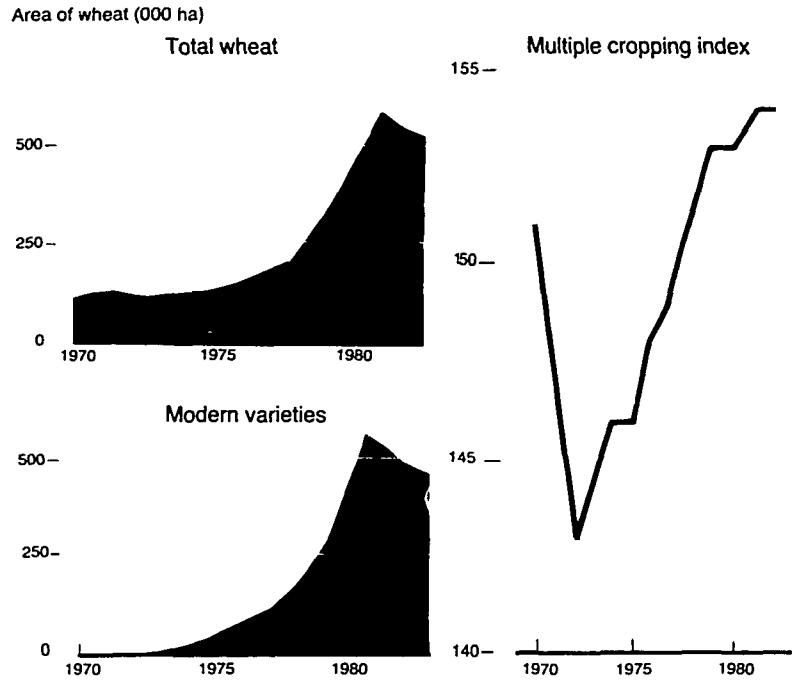
IRRI is promoting the use of azolla to help farmers to lower their fertilizer expenditures. Vietnam and China are using some strains in this way, and IRRI has fostered the exchange of azolla strains among other countries.

A study in the southern Philippines in 1981 found azolla being cultivated on 5000 hectares of irrigated rice lands. Farmers who used azolla were able to cut the use of nitrogen fertilizer from about 40 kilograms per hectare to 20 kilograms per hectare without lowering yields.

Distribution of benefits

The economic position of the very poor, who have few assets other than their own labor, is undermined by population growth, unequal land ownership, and global, political, and technological trends that reduce the prices of such things as tractors, weed killers, and imported dairy products. The poor would have been even worse off without modern wheat and rice varieties, which made possible increased cropping intensity, raised labor demand, and lowered food-grain prices. Most other innovations related to the centers' work have not yet been adopted widely enough to have measurable impacts.

Spread of wheat in Bangladesh: Fast-maturing modern wheat varieties have enabled farmers in Bangladesh to increase cropping intensity and to expand total wheat area nearly five-fold.



Modern varieties and the poor. The advent of modern varieties has affected the poor by changing their technological options. Modern varieties are more responsive to fertilizer than traditional varieties, making investment in fertilizer highly profitable. For farmers who use fertilizer, the yield advantage of modern varieties has grown as their resistance to insects and diseases has broadened, even in areas where the crop is subject to periodic dry spells. Contrary to some notions,

modern varieties yield better than most traditional varieties even without fertilizer.

Another reason behind the widespread adoption of modern varieties is quick ripening and insensitivity to length of day. Those features encourage double cropping, which smooths the flow of food supplies available to farm families during the year. The poor benefit in particular because they have difficulty saving from one harvest to the next or borrowing when a lean harvest occurs.

Drought resistance is another attraction of modern varieties. Because breeders have placed emphasis on improving root structure, some modern varieties withstand dry spells better than traditional varieties. This feature especially helps farmers in regions where irrigation or rainfall is unreliable and who, consequently, usually are poorer than farmers who have more assured sources of water.

Poor farmers, who tend to lack the knowledge and ready cash to use chemicals to combat insects and diseases, have gained from the wide range of genetic resistances that has been bred into modern varieties. The heightened disease and insect resistance of these varieties has lifted average yields without eroding maximum yield potential.

Nevertheless, many of the poorest people are in difficult environments, such as semi-arid zones or in rice-growing regions with unreliable rainfall, and they continue to grow traditional varieties. The modern varieties developed so far have offered insufficient advantage for such conditions. Significant change in these areas is likely to occur only when better varieties of drought-tolerant crops such as millet or

Research & development

The lesson of history is that technological change in agriculture is a driving force for economic growth. Over the ages, new knowledge leading to agricultural innovation has allowed more food to be produced while releasing capital, labor, and, indeed, land for nonfarm pursuits. The expanding output itself is a source of additional rural employment. Rising employment and incomes in turn expand demand for food.

In many of the developing countries that are suffering economic crises, the root cause is inappropriate policies combined with neglect of the research and extension system.

Food supplies. During the past two decades, food production in developing countries has expanded somewhat faster than population, but progress has been uneven. Annual increases in cereal output have ranged from 1.5 percent in Africa to 4.6 percent in China. Increases in production of roots and tubers ranged from 1.0 percent in Latin America to 5.7 percent in India. Increases in grain legumes ranged from nil in China to 2.7 percent in Africa. With population growth slowing, staple food production in aggregate is likely to continue to stay ahead of population, given a continuation of other contributing trends.

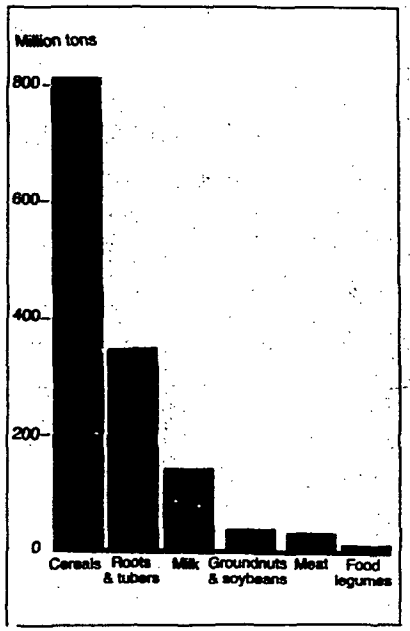
Paradoxically, food imports are also expected to grow. Rapid urbanization and rising incomes in successfully developing countries create a powerful demand for additional food, which historically has exceeded the growth capacity of even the most progressive agricultural sectors. The food imports must, by and large, come from the industrial nations that have surplus capacity.

In fact, despite the growth in agricultural production, fostered in part by increased investment in research, the developing countries as a whole have not become less dependent on imported food. Every region imports more food than it did a decade ago—but some countries have done very well. In the late 1960s, food imports by developing countries were 2.4 percent of domestic production; now they are 10 percent.

The most important force behind these growing imports is, however, rising incomes. People in areas with larger incomes can afford more food and they are willing to pay, even if importing is necessary. So, development progress tends to increase food imports. Unfortunately, in some countries expansion in imports is caused by the inability of production to meet even normal increases in demand.

Productivity. Generally, the developing regions that have achieved the best record in expanding food production during the past 20 years are ones whose farmers have raised their yields. As an indicator of progress, yield per hectare is fairly easy to measure and the data are widely available. But it is not necessarily the appropriate indicator in every situation. Land is not the critical limiting resource for all farmers. Changes in the productivity of labor-short, land-abundant farmers would be better measured by yield per person. Similarly, yield per hectare is not the most suitable indicator of progress for research aimed at improv-

Food output: Production of major food groups in developing countries 1979-83.



ing yield stability or promoting more intensive production by shortening the growing season or by introducing a crop in an area where it was not previously grown.

Research as an investment. Money has limitless uses. When policy makers act to support research, they are making an investment decision. As an investment, agricultural research has often proven to have very high rates of return, but long lags usually occur before the returns begin to flow.

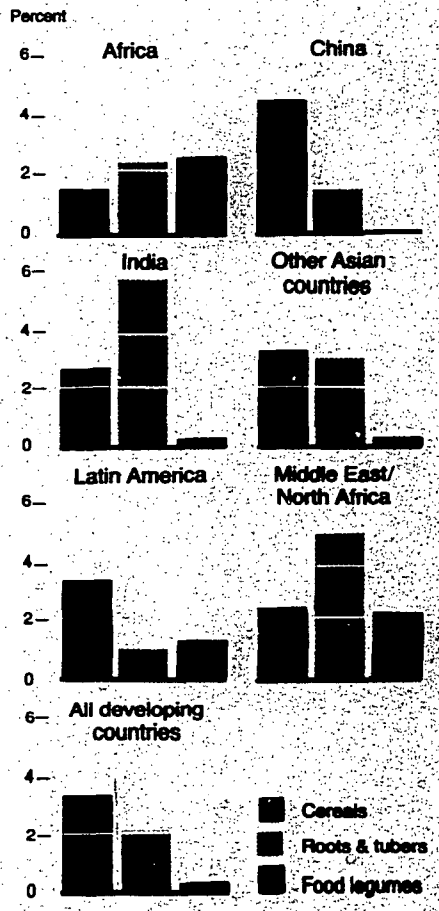
Investment in agricultural research in developing nations is largely made by public rather than private entities. The greatest need in these countries is for biological rather than mechanical technologies. The benefits from a biological innovation, however, are far more difficult for the inventor to capture than are the benefits from an industrial innovation.

The elusiveness of the benefits sometimes keeps governments from adequately supporting research. On one hand, only some of the benefits accrue to the country that finances the research; on the other, research financed by some other entity will produce some benefits that are free to any user. The creation of regional collaborative research networks is one way to share the cost of generating research benefits.

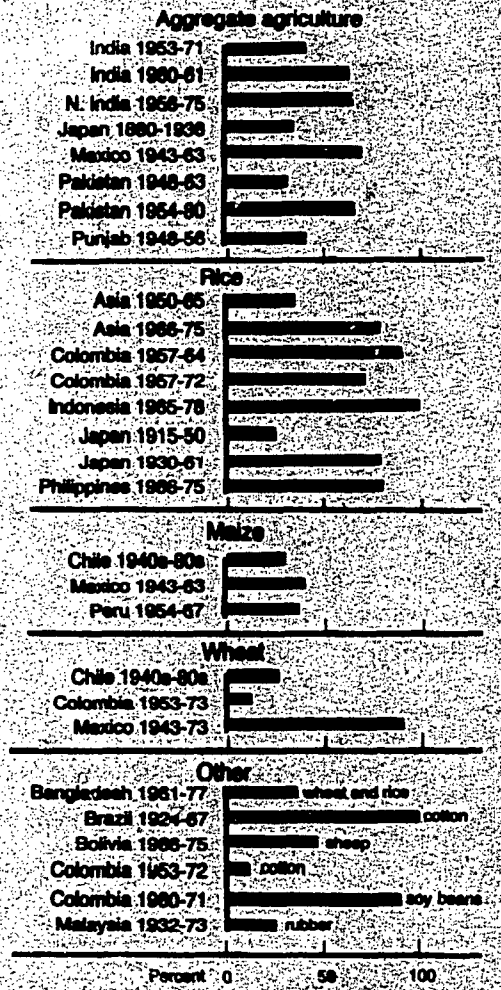
The rise of the national systems and the centers. Many national research programs on food crops were born in the 1950s and 1960s when population movement to the cities accelerated and increased food supplies were needed to keep urban masses fed. Usually these programs involved wheat or rice, the staple foods in many countries. The first international research centers also worked on these important crops and focused on Asia where famine was widely predicted in the 1970s. Land was scarce, so the primary research goal was high yield. In collaboration with national programs, they were immensely successful in generating and diffusing new technology at low cost for fertile, well-watered, densely settled areas.

Research and societal problems. Most studies of research investments in various developing countries have shown high rates of return, even for aggregate agricultural research, but, of course, studies are seldom conducted in agriculturally stagnant countries. While rates of return provide an overall measure of the benefits from research, interest in how the benefits are apportioned within a society has been rising. Precisely which distributional ills should be addressed and what research strategies are appropriate tools to redress imbalances are not well understood. Clearly, however, introducing the equity issue compounds the difficulty of setting research priorities. The centers will nevertheless have to examine the issue more thoroughly, so that limited research resources will not be scattered inefficiently over a host of competing objectives.

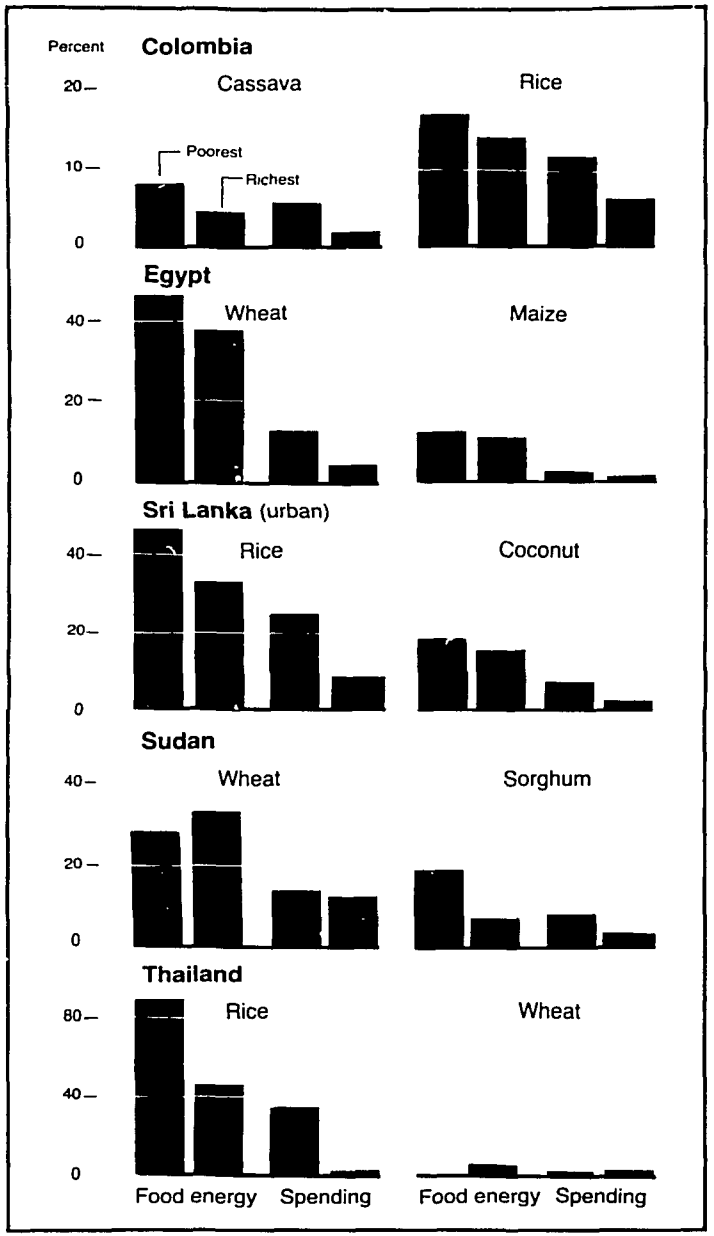
Food production increase: Annual production growth rates for major food groups in regions of the developing world.



Research payoff: Annual internal rates of return for investment in various countries: agricultural research overall, for rice, for maize, for wheat, and for other commodities.



Staple foods and the poor: Compared with the richest 10 percent of the population, the poorest 10 percent get a larger share of their food energy from staple foods and devote a larger share of their food expenditures to staples.



sorghum become available or when techniques that raise water-use efficiency, such as micro-irrigation, can be used to support modern varieties of the less drought-tolerant crops.

Farm size and adoption. There is no general association between farm size and the adoption of modern varieties—at least of rice and wheat. In some areas, a higher proportion of large-scale farmers adopt, while in others, a higher proportion of small-scale farmers adopt.

In areas where modern varieties have taken hold, the first adopters usually have been the growers with larger farms, but those with smaller farms have soon caught up. Early adopters capture some extra benefit by increasing their output before general output expansion pushes prices down. Smaller farmers sometimes lag in adoption because they wait until a better-off neighbor has proved the new varieties or because they cannot get scarce inputs at first. But once smaller farmers adopt, their ability to mobilize more family labor per hectare often gives them higher yields.

The sharpest contrast between adopters and nonadopters is not rooted in farm size or tenure, but rather in regional differences in natural resources. This is dramatically shown in India. In some regions, a substantial proportion of all farmers have adopted modern varieties. But in others that lack irrigation and have poor soils, few with any size of holding have adopted. These areas tend to have concentrations of the poorest people. Resources are distributed fairly evenly in such regions, thus, should suitable technologies be introduced, the benefits could be rather equitably shared.

Employment. Modern varieties expand demand for labor, particularly at harvest when more people are needed to reap and thresh the higher yields. Wages, however, do not tend to rise because the supply of laborers is large, mobile, and growing. Nevertheless, the modern varieties provide jobs and income for innumerable people who would otherwise go without.

The increased output possible with modern varieties has a less pronounced effect on demand for land, but, because of the restricted supply of land, rents and land values rise.

Nutrition. The effect of modern varieties in stabilizing food prices has been especially beneficial to the very poor, as demonstrated by research studies at IFPRI and other centers. In low-income countries, the poorest 20 percent of the population spend 60 to 80 percent of their income on food. When population growth and rising incomes in other parts of the economy raise demand and food prices, the poor suffer. The greatest gains for the poor have come when modern varieties have increased production of foods on which they spend a high proportion of their income. Because food expenditures consume such a large part of the income of the poor, a reduction in the price of a food improves their real incomes relatively more than it does the incomes of the wealthy.

The spread of modern varieties has helped to increase availability of food energy, the principal nutritional deficiency of the poor, and has prevented starvation of millions in Asia. Since protein in diets is mostly unavailable until the body's food energy requirements are met, research di-

rected toward increasing the quality or quantity of protein rarely contributes to significantly better diets for the poor, except where legumes are unimportant and root crops or bananas are the staple foods.

Expanding scientific and technical capability

Training was part of the charters of the first centers. From their inception, IRRI and CIMMYT trained scientists in research techniques. They also provided facilities for conducting research as part of master's and doctoral degree work.

All centers regard upgrading the capabilities of scientists and technicians of national research programs as vital to their mission. Beyond the continuing innovations of their farmers, nations that are weak scientifically cannot effectively develop their own technology or improve imported technology.

Between 1959 and 1980, the number of agricultural researchers in developing countries rose from 14,700 to 63,000. During that period, over 16,000 of them participated in the various types of training provided by the centers.

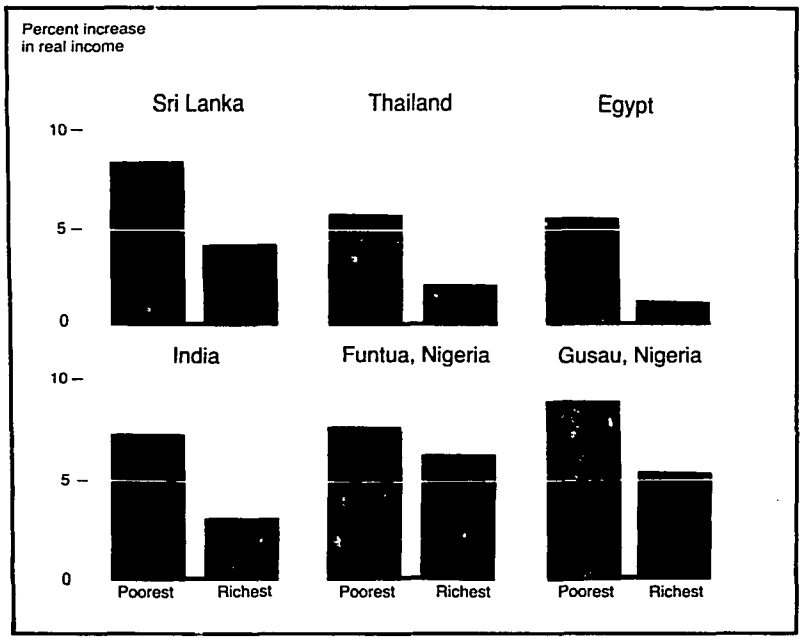
Over 12,000 have been in formal group training courses. Such courses last from one week to several months. Some are production courses covering a whole crop season to permit participants to take part in the full spectrum of production tasks. With rising frequency, the centers are collaborating with national agencies in conducting formal training programs locally.

About 400 candidates for doctoral degrees and 800 candidates for master's degrees—most of them men—have done their thesis research under the supervision of centers' staff members. Usually this work takes 2 to 3 years. Some of these graduate students attend a university near the center, but many are students from developing countries enrolled at universities in industrial nations. For the latter, thesis research at a center is likely to be more pertinent to conditions at home than research they might otherwise do at their university.

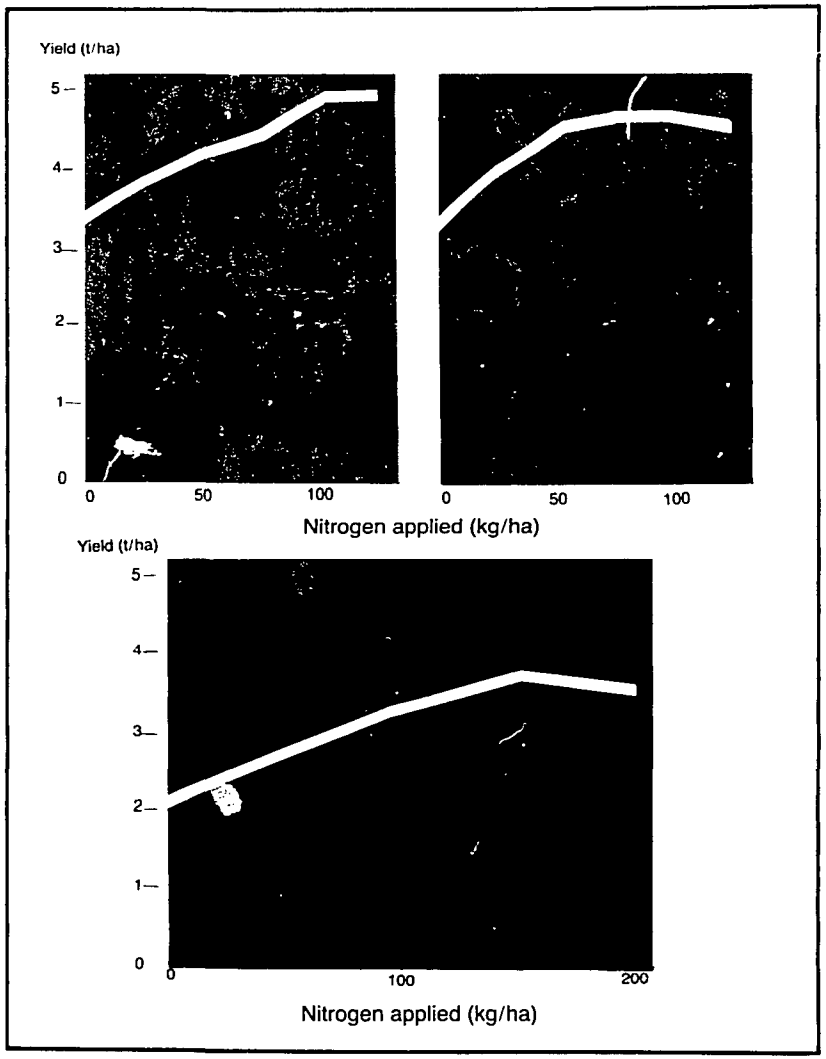
Special training programs have been set up for about 2300 individuals from developing countries. These are people who come to a center by prearrangement to learn a technique or to cover a specially organized series of topics. In addition, over 450 researchers from developing countries have held post-doctoral appointments at the centers. In these posts, the researcher learns new techniques and conducts research, which is beneficial to both the researcher's home country and the center's research program.

The willingness of administrators in developing countries to release scarce personnel for substantial periods and to assure them of positions on their return demonstrates the high regard that they have for the training provided by the centers. Many former participants, who have been interviewed, speak not only of gaining knowledge and technical skills, but of personal growth in dedication to both physical and intellectual work, motivation, determination, purpose, and confidence. For many individuals who were educated in systems that stress theoretical knowledge, the centers' training in the field or laboratory instills practical competence and understanding.

Food prices and the poor: A 10 percent drop in food prices raises the real income of poorest 10 percent of the population more than that of the richest 10 percent.



Yields with and without fertilizers: Modern varieties give slightly higher yields than traditional even without fertilizer and give a much higher response to fertilizer application (30 experiments with rice in the Philippines, 18 experiments with rice in India, 25 experiments with sorghum in India).



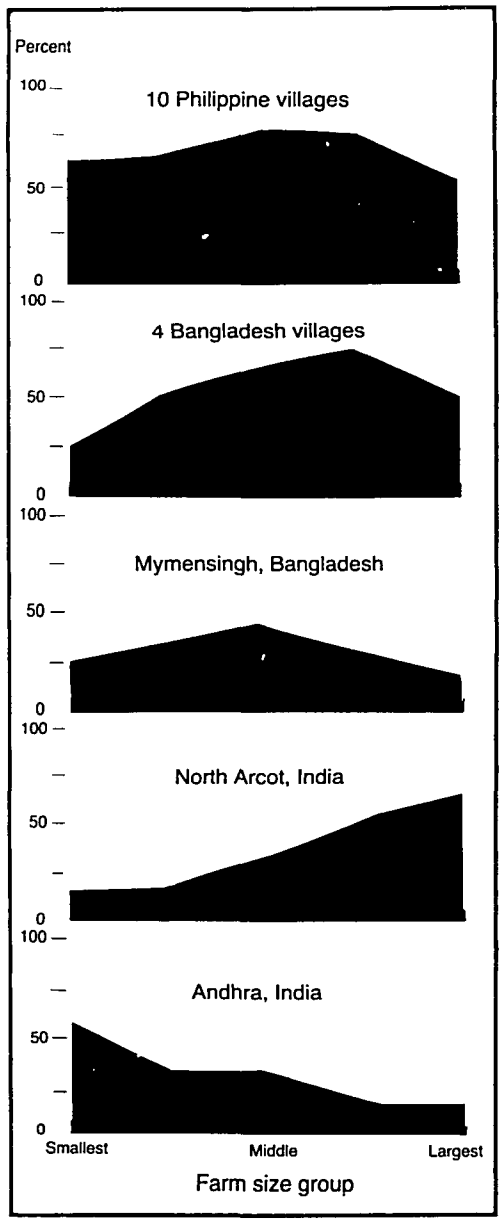
Former trainees who work in national programs are also important for the centers as cooperators in research and dissemination. Naturally they are often sought out by visiting center researchers. They may be invited back to the center to participate in workshops and to help in the training of others. These contacts are valuable for the national program as well. They help offset the sense of professional isolation and the risk of obsolescence that is difficult for researchers to avoid in nations that have small scientific establishments.

Developing nations' perceptions of their training needs are shifting as their development evolves. Demand for postgraduate training is growing, but the centers scarcely have the capacity to meet those needs. Developing nations' interest in group training within their own borders is also increasing. Such courses are jointly taught by centers' staff and, usually, former trainees. Such training is particularly suited to production courses, allowing the centers to devote their headquarters' facilities to research-related training activities.

Stronger research institutions

The centers and national research programs reinforce each other's work. The reputations of the centers have added credibility to the work of the national scientists associated with them. Collaboration with the centers has raised the productivity of national research and helped to convince governments and donor agencies that there are high returns to investment in research. But countries that lack

Farm size and adopters of modern varieties: Proportion of farmers in different farm-size groups who grow modern rice varieties.



researchers to do adaptive research, and effective extension workers to spread new ideas, gain less from the centers.

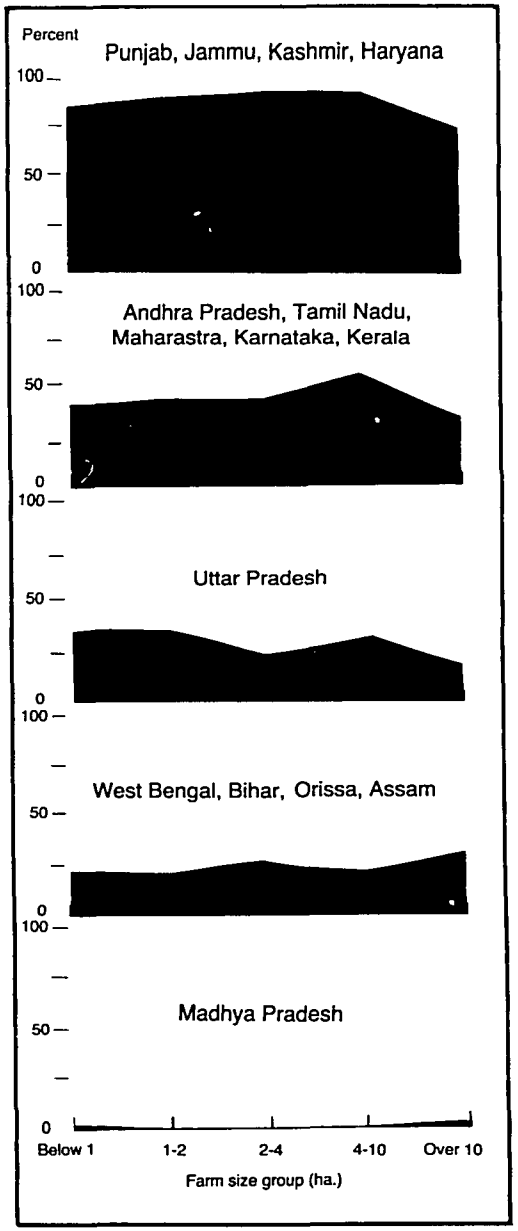
The centers have helped to stimulate nations to increase research output by improving organizational structure, by instituting better research management techniques, by making advances in research methods, and by shifting priorities toward food crops. The centers have also helped developing nations increase their contacts with scientists worldwide through database services, international meetings, and publications.

Many national programs have adopted the centers' procedures for making massive numbers of crosses and exposing them to intense attack by insects and diseases to identify the most hardy lines. Some techniques have also been developed collaboratively. An example is the procedure for mass-producing inoculum of downy mildew, a devastating disease of maize, developed by research workers in the Philippines and Thailand, in collaboration with CIMMYT.

Some national research programs have made immense progress during the past 20 years, but others remain weak. In Asia, the long-term support that research has received has been amply repaid through the growth of the region's food production. In Africa, there has been less payoff, in part because investment in research started later, and the base of commodity-specific knowledge was generally lower.

Influence on priorities. The research priorities that the centers set, their direct efforts to strengthen national institutions, and the regular services that they provide, all have some effect on the directions

Farm size and adoption of modern varieties: Proportion of rice area planted to modern varieties in relation to size of farm (all locations are in India).



taken in national research. Before the 1960s, few developing countries spent much for research on their staple food crops. That changed after the centers were created. In Bangladesh, for example, investment in rice research went from being a fraction of the amount in jute research in the 1960s to being four times as much by 1980. Before the advent of ICARDA with its emphasis on field crops, less than half of Syria's research projects involved field crops. By 1984 about 75 percent of the national research projects were on field crops. Before CIAT and IITA began cassava research, only India had a national cassava program. Now two dozen nations have one.

Occasionally, the reaction to the centers' priorities is inordinate. Sometimes the portion of national research resources devoted to an area that the centers work in has been disproportionate to the possible contribution of that area to output. On the other hand, occasionally, a national research system will shift support away from an area that is well-covered by a center. But these instances are rare and not necessarily irrational.

Perhaps the most important influence of the centers on the national programs has been rising emphasis on research directly aimed at solving farmers' problems. Since research workers at the centers tend to have high prestige and to serve as role models, their demonstrated interest in field work and on-farm trials, along with the stress given by centers' training programs, has been emulated in many national programs.

The centers have also set an example by demonstrating the productivity of problem-oriented, multidisciplinary research.

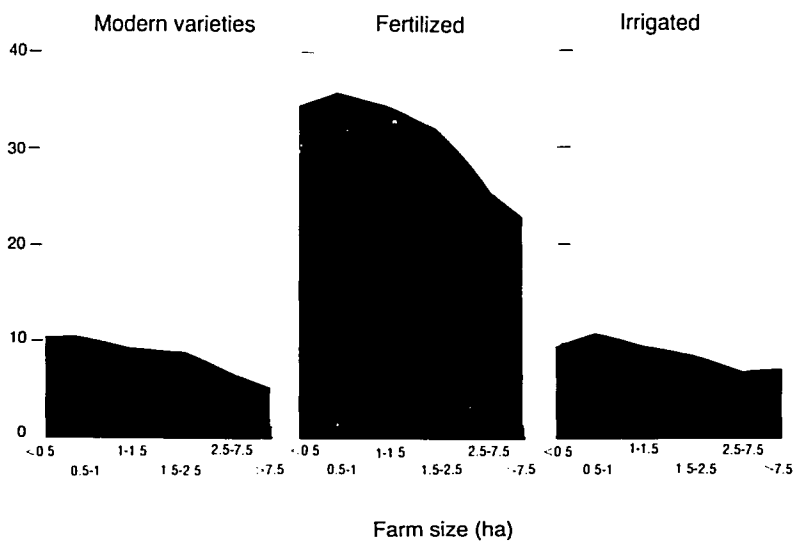
In Brazil, for instance, the national research structure was reorganized into multidisciplinary commodity institutes along the lines of the international centers.

Direct assistance. Aside from providing germplasm and training, the centers assist national research programs with ideas for methods, techniques, and research management. Direct help in strengthening the organization and structure of national agricultural research systems is the mandate of ISNAR. In addition, it provides some training in research management.

Another example of direct help is the analytical service that ILCA provides to national agencies that have large databases on animal production. National researchers get assistance from ILCA staff in analyzing the data, and the results are sometimes used in designing projects for funding by donors.

Research networks promoted by the centers have encouraged countries to expand their research capacity and to cooperate in sharing research results. Networks that test biological materials have accelerated the development of new varieties through international multilocation testing. Data on a breeding line tested at many locations in one year can be a partial substitute for tests on a line at one location over several years. Multilocation testing also provides readings on the response to certain types of stresses that could not easily be determined otherwise.

Farm size and modern technology in Bangladesh: Proportion of area planted to modern rice varieties, fertilized, and irrigated, by farm size.



Sound policies

Need for food policy research. For the past two decades, in years of bad harvests as well as good, the global supply of food energy has exceeded the world's nutritional requirements by a substantial margin. Nevertheless many millions of people remain ill fed. The gains in total food production are unevenly distributed from country to country, from region to region within countries, and among households within regions.

Those inequities are in part the result of policy decisions, both national and international, that affect the onset and impact of technological change. Attempts to influence the level of food production and consumption require attention to the economic, political, and institutional setting as well as to technological questions. Consequently, research that deepens understanding of the nature and role of domestic and international policy and thus leads to better decisions is an important element of global agricultural research.

In its broadest sense, agricultural and food policy embraces the collective efforts of national and international agencies to alter the environment of producers, consumers, and traders. Food policy analysis is concerned with such issues as food production, consumption and nutrition, the generation and diffusion of new technology, the enhancement of physical and human stocks of capital, the distribution and pricing of food, and the role of trade and international policies.

IFPRI is fully devoted to food policy research; ILCA has recently formed a livestock policy research unit; and several of the other centers in the CGIAR system undertake food policy research, generally on a modest scale. At some centers, social science research of policy relevance is conducted within a department of economics or social science, but it is often linked with farming systems research. At one center, it is incorporated into the work of multidisciplinary commodity teams. The focus of this work at the centers is on policies to enhance the generation and diffusion of new agricultural technology. Outside of IFPRI and ILCA, there is little research in the center system that is directed specifically at food and agricultural policy.

The individual centers must stay abreast of the policy environment in countries where they have working relationships with the scientific community.

This type of monitoring enables a center to allocate its own resources better and, at the same time, to discuss policy questions with national authorities on the basis of current conditions.

Through collaboration with national scientists in the development of new technology, both economists and biologists from the centers have had access to national policy makers. The introduction of significant technological change causes disequilibria that compel action from policy makers.

When they recognize the magnitude of the potential gains from the new technology and understand the distribution of the costs and benefits, policy makers become acutely aware of the burden imposed by shortages of inputs, inadequacies of transport and processing facilities, subsidized food imports, and similar problems. Thus, while most of the centers focus on generation of new technology, they are quite legitimately involved in policy discussions.

Effects of policy work. Any credit that the centers could claim for constructive policy changes made by national leaders would be empirically difficult to support. It is evident, however, that such work as IFPRI's research on input policies, food security, crop insurance, and food subsidies; CIMMYT's policy seminars; and IRRI's research on the consequences of new technology has contributed to a more informed debate and has been in demand from policy makers.

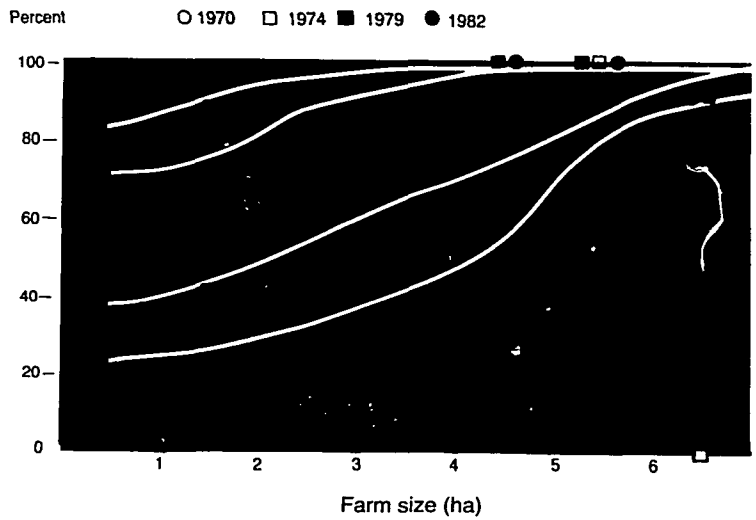
IFPRI is the central institution in the research on agricultural and food policies. Together with the commodity-oriented centers, it gives the CGIAR system the capacity to review both the on-farm constraints and the policy constraints to greater food production and improved welfare. The joint application of this capacity is illustrated by the IFPRI/IRRI research on irrigation in the Philippines, which contributed to the Asian Development Bank's decision to reconsider its plans to curtail investment in Philippine irrigation schemes.

Another example is Egypt, which spends $2 billion a year on food subsidies. Analyses made in collaboration with IFPRI showed that the country could save hundreds of millions of dollars annually without jeopardizing the food security of the poor.

The contribution of policy analysis lies in its direct effects on policy, and, as well, in the credibility it gives policy analysis in national agencies. Many governments neglected this area in the past. The efforts of the centers, and of IFPRI in particular, have demonstrated that providing policy makers with better information about strategic alternatives can lead to broad and significant gains. And policy makers, for their part, have become further convinced of the value of building domestic capacity for research on policy issues.

Food policy research has been internally beneficial to the centers, too. Support for assigning secondary priority to breeding for higher protein content came from research policy studies that showed that better protein nutrition could be achieved more economically by focusing on high yielding and widely adapted varieties.

Adoption of rice varieties on small and large farms: Surveys in the Central Luzon area of the Philippines show the tendency of small farms to catch up to large farms in adoption of modern rice varieties.



Relations with the centers: The national viewpoint

Case studies completed in 25 countries, which included interviews with usually 40 to 50 persons in each country, have provided a basis for assessing the opinions of researchers and others in national programs about the staff and activities of the international centers.

Contacts. Most national scientists who collaborate with the centers hold a favorable view of the quality of their professional association with scientists from the centers. They consider their sustained relationships with centers' scientists to be an important ingredient of successful collaborative research and they contrast the continuity of those relations with the abrupt changes in personnel and support that often occur in bilateral projects every few years. National scientists have occasionally felt that some centers' researchers were overbearing or unqualified, but the instances have been isolated and generally seem to have passed as collaborative relations between national programs and the centers have matured.

Each center has focused its contacts on researchers who work with commodities or problems that the center regards as important. In the early years of the CGIAR system, that meant that researchers in some countries were bypassed. But as more centers have been created nearly all developing countries now have some professionals in touch with one or more of the centers. Observers in several countries have said, however, that researchers on university faculties tend to be overlooked by the centers.

Favored services. National scientists regard the channels for exchange of germplasm established by the centers as a unique service. Overall, they consider the workshops, conferences, training programs, newsletters, and publications of the centers to be more valuable than those available from most other sources. Research networks are appreciated particularly by scientists in countries that have small research establishments. Such networks allow several countries to specialize on different aspects of a common problem and to exchange results for common benefit. In addition, participation in a network raises the professional status and motivation of national researchers.

Coverage. Whether the centers are addressing the right research topics tends to be viewed differently in countries where centers are located than in countries without centers. Scientists in countries that have a center headquarters often feel that the center's global or regional outlook diverts attention from their country's special problems. When a center's researchers are outposted to another country, their interests are seen to be more in consonance with those of the indigenous scientists.

The centers, many of which were created to help increase food production, are not surprisingly believed to have had a salutory effect on the work of researchers who likewise work on food production. The development of national programs on neglected crops like cassava was, national researchers say, due largely to the efforts of the centers.

National researchers see some gaps in the coverage of the centers. They point out that many poor farmers cultivate fiber crops such as cotton, jute, and kenaf, oil crops such as copra and palm oil, and beverage crops such as coffee, tea, and cocoa, none of which are handled by the international centers. While research on industrial and export crops might be primarily beneficial to plantations, it would also help the small-scale producers who rely on them and, particularly for tree crops, contribute to stabilizing land and providing income in vulnerable environments.

Genetic materials. From the vantage point of national programs, among the most important contributions of the centers is the provision of genetic materials. Seeds and clones bearing a profusion of useful characters give national plant breeders more choices. And that improves their odds of producing and identifying lines that have the features necessary for good results in farmers' fields.

Some international nurseries, such as the U.S. Department of Agriculture wheat rust nurseries, were in operation before the centers were founded, but the nurseries coordinated by the centers are accessible to far more countries and facilitate the routine distribution of useful germplasm. Small-scale breeders no longer have to describe their needs to solicit seed from breeders who have large crossing programs. Instead they receive a steady flow of material with tested resistance to diseases, pests, and adverse conditions. The centers deliberately include a diverse selection of strains in most nurseries to ensure that something will be of interest in nearly every ecological niche.

International exchange of vegetatively propagated crops was almost nonexistent prior to the start of the cassava programs of CIAT and IITA and the potato program of CIP. In food legumes, the exchange of germplasm was sporadic and informal before the centers began international testing programs for such crops as field beans, cowpeas, chickpeas, and pigeonpeas.

Aside from making superior genes widely available, the international nurseries have broadened the horizons of breeders. The nurseries allow breeders to compare, in their own test plots, the yield performance of hundreds of lines from abroad. In cassava, for example, this experience has led breeders to see 40 tons per hectare as an achievable target where they once thought 20 tons per hectare was excellent.

Breeding techniques. The centers have been vigorous in passing on research techniques. Since plant breeding is in many respects a "numbers game," the ability to make many crosses and selections efficiently is a significant determinant of a program's output. The centers have trained numerous persons in the physical skills of making crosses and monitoring test plots. The vacuum emasculation techniques promoted by IRRI has boosted the productivity of rice breeders in many countries. The spread of techniques for mass rearing insects and for collecting and inoculating disease pathogens has enabled breeders to screen lines for resistance on a much larger scale.

The interaction with centers has also encouraged breeding programs in a number of countries to take an interdisciplinary approach. Instead of the breeder being limited to breeding and the entomologist and pathologist being confined to resistance evaluation, they collaborate in planning crosses and selecting materials for multiple resistance.

Farming systems research. The effect of the centers' emphasis on farming systems research on national programs has been uneven. Although many countries have begun farming systems research programs, not the least because of the urging of donors and the help of the centers, the impact has been more significant when national programs have managed to integrate the concept of farming systems in the research structure and less perceptible when the program has simply been added alongside existing commodity programs. The flow of information back to researchers about on-farm problems has been useful within both national programs and the centers.

Training. Many national researchers rate training by the centers as equal in importance to the provision of germplasm. Participants appreciate the knowledge acquired, as well as the opportunity to mix with colleagues in other countries. The contacts often lead to the formation of networks and continuing professional correspondence. Training courses brought from a center and mounted locally have been found particularly useful by national programs.

Perceptions of the centers' training programs can differ among countries and even among institutions within a country. Some countries with large numbers of highly trained researchers have only limited interest in the courses that the centers offer. There are instances, too, where researchers at a large, relatively well-

National agricultural research systems

National agricultural research systems in developing countries have grown rapidly during the past 25 years. The greatest change has occurred in Asia where real expenditures on national research has risen in almost every country. There was an initial period of institutional instability, but most countries now seem to be developing effective national systems.

In Latin America, overall, research systems grew rapidly, too. But unlike Asia, real research expenditure in some countries declined during the 1970s. There was also a period of reorganization in several countries.

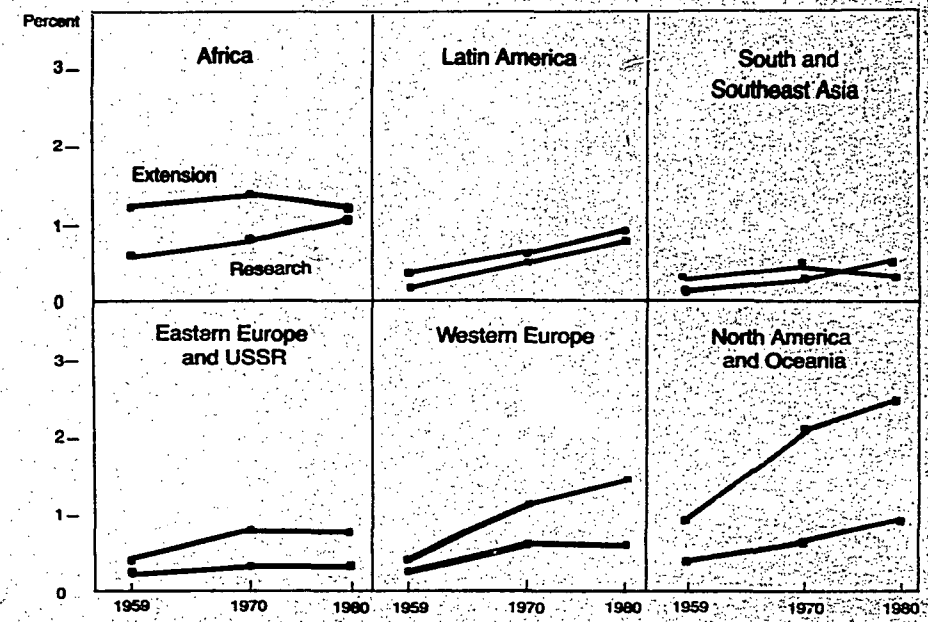
In Africa, aggregate growth in research expenditure was high but there was considerable variability by country. Many African research systems were disrupted by larger national problems after independence. Some research systems suffered radical changes, while some others remained highly dependent on, or under the control of, foreign researchers.

Political pressure by consumers for reliable food supplies was one of the basic reasons for the growth of agricultural research expenditures, particularly in Asia in the 1960s and in Africa in the late 1970s and 1980s. The urban sector also wanted more foreign exchange for importing industrial and consumer goods, which could be achieved by reducing imports of food and raising exports of agricultural commodities. These groups induced governments to invest in agriculture in order to provide adequate food and to maintain economic and social stability.

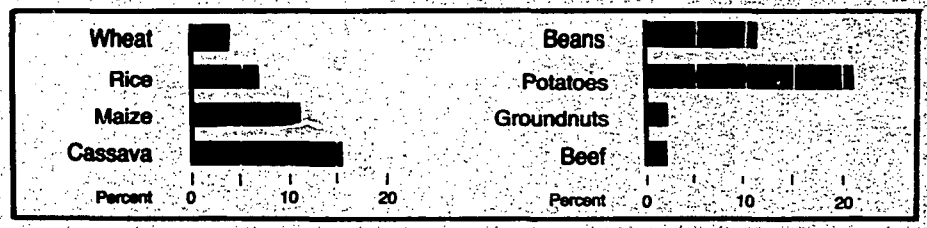
During the 1960s, it became increasingly clear that agricultural research was a powerful instrument for increasing output. The rates of return to agricultural research in Asia and Latin America were high. The impression made by the green revolution changed perceptions in developing countries and among development agencies about what research could do. Since many countries in Asia and Latin America no longer had cheap land to exploit for increasing production, they increased investment in research as one answer to the demands for more agricultural production.

Weaknesses remain in many national systems. Educating and retaining enough researchers to conduct meaningful research is a chronic problem. Moreover, many research programs are not well enough organized to make efficient use of the resources they have. Some significant commodities continue to be neglected. The international research centers have helped national programs, by example and through advice, to overcome these difficulties.

Research funding: Government spending on agricultural research and extension in relation to agricultural output.



Spending by centers as a share of agricultural research expenditures in developing countries.

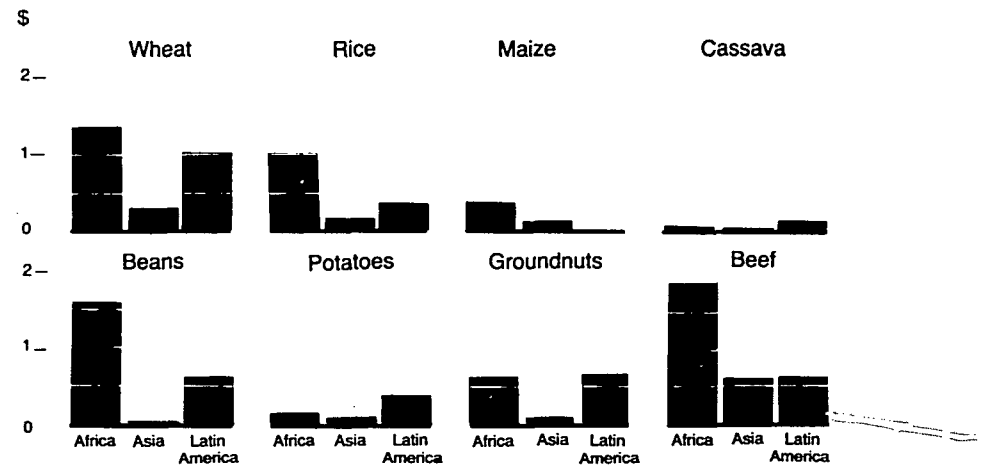


Small research programs: Indicators of the scope of national research programs in small countries.

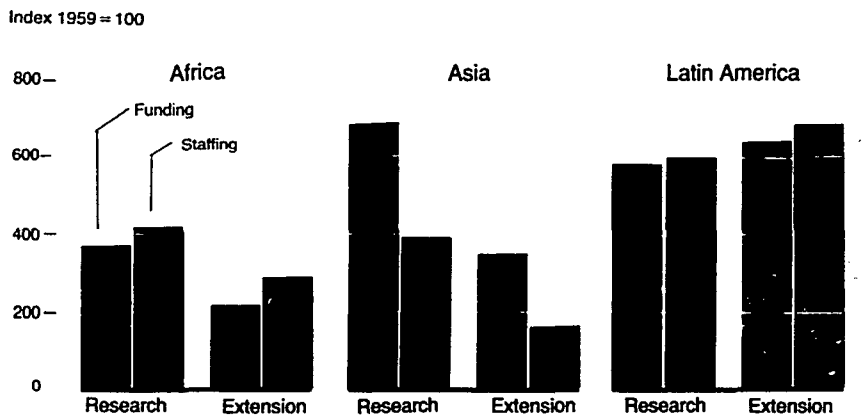
Country	Crop area million ha.	Agricultural researchers number	Agricultural researchers number per million ha.	Research expenditures $/100 ha.
Countries with under 50 researchers				
Cape Verde	0.04	6	150	n.a.
Tonga	0.05	8	151	540
Solomon Islands	0.05	8	154	640
Mauritania	0.20	9	46	435
Lesotho	0.29	13	45	96
Gambia	0.27	13	48	28
Benin	1.80	21	12	96
Barbados	0.03	23	697	1518
Fiji	0.24	23	93	650
Somalia	1.07	28	26	45
Burundi	0.98	28	29	68
Guyana	0.38	35	92	417
Haiti	0.89	37	42	27
Chad	3.15	40	13	31
Malawi	1.31	41	31	181
Jamaica	0.27	41	151	191
Trinidad & Tobago	0.16	43	272	265
Liberia	0.37	45	121	185
Mali	2.05	47	28	182
Togo	1.42	49	35	87
Countries with under 25 researchers/million hectares				
Uganda	5.7	58	10	85
Ethiopia	13.9	145	11	21
Zaire	6.3	97	15	53
Nigeria	30.4	491	16	262
Niger	3.6	59	18	35
Zambia	5.1	96	19	21
Senegal	5.2	105	20	122
Sudan	12.4	272	22	77
Cameroon	6.9	156	23	48
Comparative regions				
India	169.1	2345	14	73
N. America & Oceania	280.5	13607	49	6190
Brazil	7.1	2935	41	244
W. Europe	95.0	19540	206	1570

Research intensity: Research spending by commodity in relation to the value of the commodity ($ per $100 of commodity value; 1972-79).

Africa: Ghana, Kenya, Nigeria, Sudan, Tanzania, Tunisia, Uganda, Egypt. *Asia:* India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Turkey. *Latin America:* Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela.



Growth in research and extension: Changes in funding and staffing of research and extension programs (data for 1980 as a multiple of 1959).



funded national institution rate germplasm as being a more important contribution than training, while researchers at smaller institutions in the country see training, especially with the centers, as their major need.

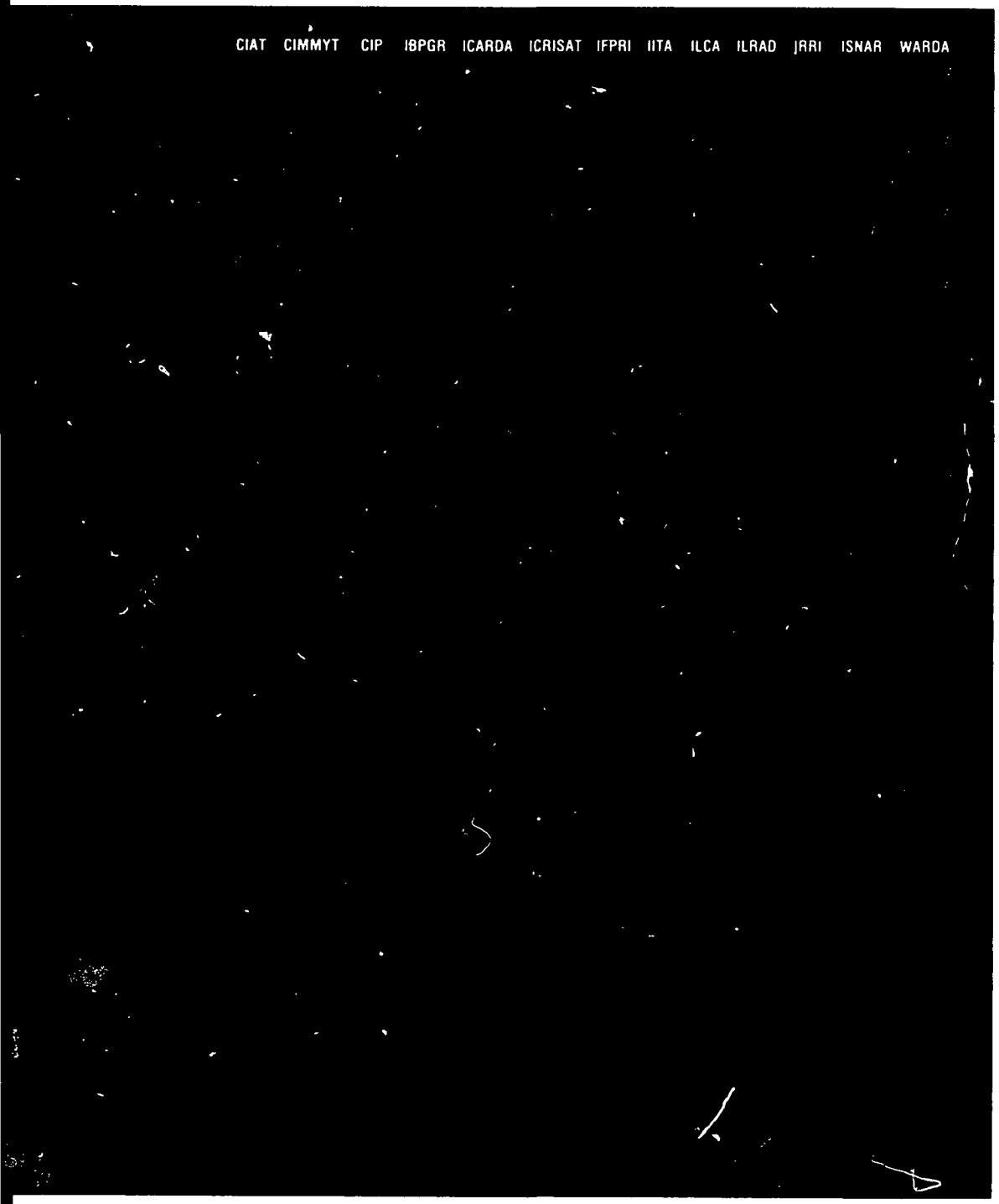
Many national researchers would like the centers to offer more post-graduate scholarships and post-doctoral positions as well as more opportunities for students who are studying in industrial countries to do their thesis research at a center.

Publications. National scientists are eager to receive centers' publications, particularly the more technical ones giving details of research methods and findings. Shortage of funds, however, limits the ability of researchers to purchase all the materials they want. In particular, research workers distant from the main national research site lack the access that they desire to centers' technical publications.

Network newsletters that give individuals the opportunity to share information about their activities provide a sense of involvement to participants and boost enthusiasm for programmatic work. Researchers interviewed consistently ranked newsletters from the centers highly, indicating the value of the research information they contain.

Selective dissemination of information by various centers makes world literature accessible at low cost to researchers with whom they are in contact. The centers supply extensive bibilographies of current literature to researchers and some also provide abstracts and reprints of articles.

Intensity of centers' contacts with various countries: Schematic indicators



Influence on research investment. National researchers generally credit rising public awareness of the effects of the green revolution as having contributed to increased investment in agricultural research. Also, the existence of collaborative work with the centers sometimes is helpful in protecting national research budgets from cuts or in attracting more funds from the government.

Institutional organization and policy making. Although many research programs have undergone significant reorganization in recent years, the changes are not often attributed to the advice or example of the centers. Nonetheless the widespread adoption of the centers' style of research—a multidisciplinary, problem-oriented commodity approach—is evident. The aid of ISNAR, which is concerned with the broad issues of institutional development, has been welcomed by most countries that have received it and is sought by many others. The Dominican Republic, Kenya, Fiji, Malagasy, and Rwanda, for example, have actively implemented jointly formulated plans, while other countries have used the occasion of an ISNAR review as an opportunity for taking a fresh look at their own planning problems.

Policy issues can be highly sensitive, nevertheless many individuals involved in policy formulation indicated that they appreciate IFPRI's collaboration. They feel that their own analysis gains credibility if it is accompanied by an IFPRI analysis. IFPRI is widely regarded as a dispassionate source of independent and professional thinking on topics that are inevitably delicate.

Some important activities and issues

The impact of the centers depends largely on how effectively they and the national programs carry out their research, and on how effectively it is put into use. Some issues that relate to important research activities of the centers and their potential for future impact have been singled out for closer examination.

Plant germplasm and breeding

Global activities in the center system. Plant breeding, which leads to new varieties and improved human well-being, aims at combining useful genetic characteristics from different parents. The sources of such characteristics are farmers' varieties and wild relatives of the crops. Systematic efforts to collect and use a wide range of germplasm have long been under way. While the centers were latecomers to the field, they now lead the work in many food crops.

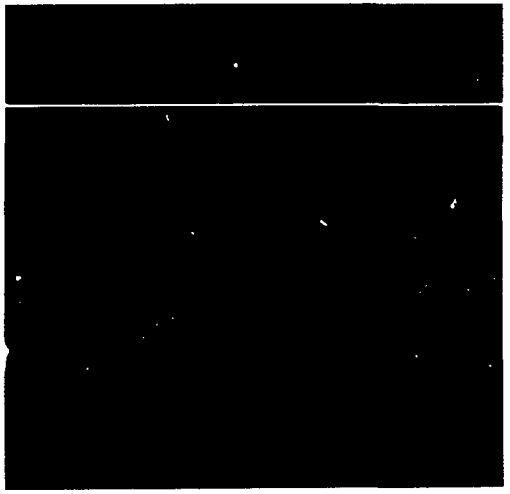
The activities of IBPGR have raised public awareness that the genetic variation stored in cultivated crops and their wild relatives is a vital natural resource. Paradoxically, though genetic variation is the basis for plant breeding programs, the effects of successful programs are antagonistic to it. The creation of highly productive, uniform varieties is an efficient way to achieve rapid agricultural progress. To do so, breeders commonly establish restricted gene pools that satisfy many of the basic requirements and then introduce new characters as needed. Genetic resources are primarily seen as a source of identifiable characters and only rarely as a source of increased overall variation.

IBPGR encourages the conservation, documentation, evaluation, and utilization of genetic resources, largely in and by national programs, with the cooperation of the CGIAR centers and other agencies. The priorities of IBPGR are based on risk of genetic erosion, economic and social importance, plant breeders' requirements, and size and scope of existing collections. It has promoted the development of networks of base collections and of national genebanks, and does not itself build or operate genebanks.

Collections in genebanks fall into two categories. A base collection is one that can be kept relatively undisturbed in long-term storage. An active collection, in contrast, is one used for regeneration, multiplication, exchange, evaluation, and documentation. Base collections must be closely associated with an active collection because base collections are not usually used for germplasm exchange. These distinctions are not widely understood and have led to unwarranted charges of restrictions on free flow of germplasm.

IBPGR has helped to organize 300 collecting missions in 88 countries. Seeds of 138 species collected during these missions have been placed in genebanks of 450 organizations in 90 countries. Collection in recent years has brought genebanks a good representation of the natural genetic diversity in many of the plant species that centers work on. But wheat, barley, certain millets, and tropical pasture species are underrepresented. In addition, little collection of wild species of sorghum, millet, cassava, chickpeas, pigeonpeas, and cowpeas has been done.

Germplasm collections: IBPGR's 1984 estimate of the number of accessions of major food crops held in genebanks and the comprehensiveness of the collections in relation to the variability existing in nature.



Centers' breeding approaches. The development of modern, widely adapted wheat and rice varieties constitutes a

model that breeders of other crops have had difficulty following. Widely adapted varieties are only likely to appear in relation to uniform environments. For physically or socially diverse environments, more closely tailored varieties may have to be produced.

Plant breeding at the centers has been rather centralized and largely conducted on experiment stations under good conditions, with few centers systematically attempting to simulate typical farm conditions through low-input trials. The products of breeding are subjected to multilocation testing by the centers as well as by collaborating programs. The materials in multilocation trials are freely available to any breeder for use as a parent in crosses or for release as a variety.

Despite the large scale and high caliber of the centers' breeding programs, several criticisms can be made. Centralized decisions about parents and breeding plans are bound to be less than optimal for most places, most of the time, because environments are diverse and performance is determined by the interaction of genotype with environment. In the area of resistance breeding, perhaps too much reliance is placed on major gene resistance and not enough attention is paid to building horizontal resistance (known also as multiple-gene or durable resistance), which may be less dramatic, but is more stable. And, attempts to breed varieties for small-scale farmers who use low levels of inputs are likely to be self defeating if selections are made under high-input conditions on experiment stations. Most centers are overcoming these limitations through interaction of breeding programs with the on-farm research activities of national programs and their own farming systems programs.

Farming systems research

Farming systems research employs a systems approach to apply knowledge from the natural and social sciences in order to overcome agricultural problems. Although it is an approach that has long been used by insightful researchers and is not a new, independent science, farming systems research has only in the past decade been recognized by research agencies in a way that brought it specific budget appropriations and designated program activities, so that its methods could be transferred. Consequently, not much of its potential for enhancing agricultural productivity has yet been realized.

Most of the centers have embraced the approach, and as it spreads, its concepts, terminology, and methods are evolving rapidly. There is, however, general agreement about the framework of methods.

Farming systems research examines the farm as a system in which the farmer and farm household are the principal decision unit. The approach is interdisciplinary. It includes activities both at experiment stations and on farms, and is oriented to an area or set of farmers called a target domain, delineated by broadly common soil and climatic conditions or by the relative homogeneity of the principal farming systems. The domain chosen should be narrow enough to make tangible results likely in a reasonable time, but broad enough to spread the research costs.

Since climate and weather conditions determine the likelihood of damage from many pathogens and pests, a subdivision into homogeneous soil-climate regions makes it possible to develop specific management recommendations against them. To provide more specific responses to questions about environments, several centers have entered basic environmental data for thousands of sites into computer storage, which is accessible through a geographical database-management system.

Surveys of farmers' practices, often informal but controlled, are conducted within the target domain by a multidisciplinary team. Matching genetic materials, management, and improvement methods with environments is a continuing activity of researchers. The crucial stage of farming systems research is the development and testing of possible system changes through experiment station trials and on-farm testing, either researcher-managed or farmer-managed. Extension workers are generally involved in the

on-farm testing and should join the farming systems research team in monitoring the spread of new technology.

Information from on-farm trials returns to the researchers to be used in progressive redesign of improved practices until they are well adapted to the needs and circumstances of farmers in the target domain. The information, moreover, helps researchers to redirect their priorities to topics of greatest importance to farmers, and, indeed, facilitates their learning from farmers.

Because of the inherent location-specificity of farming systems research, it should logically be implemented by national research programs. But the national programs look to the centers for guidance and help in the development of the approach and its implementation.

The centers' farming systems research has largely focused on refining research methods and supporting national programs by, for example, providing technical assistance, training researchers, developing prospective technologies, and establishing farming systems research networks. For the centers, a direct benefit of the farming systems work is that it increases the contacts between research workers and small-scale farmers.

Plant protection

The centers have significantly influenced the attention that national programs have given to crop protection through the dissemination of high quality information and through the establishment of global nurseries for testing lines and varieties under a broad range of conditions.

Resistance breeding. Resistance breeding has been the keystone of the centers' work in plant protection. From the start, modern wheats were bred for resistance to the rusts that are the most serious diseases of wheat. Many of the resistance genes from those early lines are carried by today's modern varieties and continue to be effective. Although IR8 and IR5, the first two rice varieties from IRRI, did not have high levels of resistance to major pests, the third variety, IR20, was resistant to one of the most damaging insect-virus complexes, and all the varieties that followed carried resistance to an increasingly broad range of insects and diseases.

Plant protection for other crops has also centered on incorporating genetic resistance into materials suitable for farmers. Since rate of release and adoption of new varieties of these crops does not equal that of wheat and rice, the impact has been correspondingly smaller.

It is sometimes claimed that the widespread planting of modern wheat and rice varieties has caused boom and bust cycles, but there is no reliable evidence to support that idea. Pests and diseases that have recently been newsworthy were serious problems before modern varieties existed. Unusual disease or insect outbreaks are more likely to be related to marked changes in agricultural practices, such as a switch to double cropping or the introduction of pumps that permit cultivation during the dry season, than a direct consequence of planting improved varieties.

Control measures. The centers' work with chemicals has been criticized from several sides. On one hand, they have been reproached for developing varieties that are input responsive, because that encourages farmers to increase profits by applying fertilizers, insecticides, and herbicides. On the other hand, some critics charge that the centers have avoided research on chemical control of crop pests.

There are indications that integrated control strategies, pest surveillance, surveys, and monitoring techniques developed by centers' researchers and national programs are being used by some farmers. But because at most centers the leadership of interdisciplinary teams is in plant breeding, genetic resistance is often emphasized at the expense of other pest protection strategies. Some observers believe that resistance breeding will not prove to be a sufficient control measure against serious pests of many crops aside from wheat and rice, so other strategies should receive more attention.

As the demand for food grows, while the quantity of agricultural land remains rather fixed, farmers must produce more intensively, which means that more inputs are needed. Unless alternatives are found, it may be inevitable for developing nations to become more like industrial countries in their employment of agricultural chemicals in food production systems. An appropriate activity for the centers may be expanded work on evaluation

of pesticides, including naturally derived compounds, and research on pesticide safety, in addition to other measures.

Tropical land use

The degradation of tropical land is proceeding at an alarming rate. Of the world's 1 billion hectares of tropical forest, about 440 million hectares had been cleared by 1980. About 150 million hectares were in permanent agriculture, 210 million hectares were in shifting agriculture, and 80 million hectares were so degraded that they supported only unproductive vegetation.

In many wet tropical areas, when forest is removed, soil fertility declines and erosion occurs or soils aggregate into brick-like consistency if the land is not rapidly returned to a high density cover crop. With improper clearing, the destruction may not be limited to the cleared area, and may extend to downstream fields and water supplies. Yet the question is not how to prevent all forest clearing, but what techniques of removing the forest and using the land for agriculture are most sound.

Whether the centers' work speeds or slows the degradation of tropical lands is uncertain. There is little doubt that, without the modern varieties, total grain production would have been lower and that food shortages would have placed more pressure on the tropical land frontier. Over the past decade, perhaps an additional 10 million hectares of forest would have been felled to produce the food that has been grown through more intensive cultivation of existing farm land, which was made possible by the introduction of modern varieties.

It is more difficult to speculate on the effect of modern varieties on slash-and-burn cultivation. On one hand, higher production may have caused some slash-and-burn areas to revert to a longer fallow period; on the other, lower production costs may have encouraged growers to seek short-term gains by opening marginal land that is irreversibly destroyed after a few years of cultivation.

The centers' concentration on subsistence food crops means that they are working with annual crops, which cause more strain on soils than do perennial tree crops like rubber, coconut, or coffee. Yet the centers address the more stable and productive areas in which their crops are growing because, there, technological advances have the greatest potential for increasing food production. In addition such areas are less vulnerable to overcropping. Increased attention to risky areas might cause some slackening of output gains in more stable, high production areas.

The centers are at present mainly concerned with, and judged by, the productivity (usually measured as yield) and stability of the farming systems with which they work. In order to shift centers' attention to technology for more marginal areas, sustainability (ability to maintain productivity over an extended period that may include unpredictable disturbances) and equity would have to rank with spread of varieties and increase in output as measures of the performance of the system.

The physical, social, economic, and institutional aspects of management of renewable resources in the humid tropics are numerous and highly complex. It is doubtful that the centers at present have the resources to undertake research and to seek greater involvement with the wide range of national institutions that affect the sustainability of the ecosystem under agricultural exploitation. Yet the importance of the issue is a compelling reason for the centers involved in tropical crops to continue to assess the options for research that might have an impact.

Biological nitrogen fixation

Research on biological nitrogen fixation has been a continuing component of the programs of the centers with leguminous crop mandates—CIAT, ICRISAT, IITA, and, more recently, ICARDA and ILCA. IRRI has also had a longstanding commitment to research on biological nitrogen fixation associated with rice cultivation.

Those centers have made a significant contribution of new knowledge directly through their own research and indirectly through the attention they have focused on the research needs of their mandated crops among researchers in some industrial and developing countries.

The research output has had limited application in farmers' fields. In many

instances, the potential impacts of the research accomplishments in the area of biological nitrogen fixation are masked by the dominance of other limiting factors, both agroclimatic and socioeconomic.

Research on biological nitrogen fixation at the centers has helped to improve the quality of research in national institutions. Among the scientists of the centers undertaking biological nitrogen fixation research, there are opportunities, so far unrealized, for more synergistic research efforts.

In the future, biological nitrogen fixation research should emphasize the management of nitrogen fixed biologically within the context of the cropping systems that are commonplace in tropical agriculture.

Future returns from research

It is reassuring that investment in agricultural research has paid handsome dividends in many regions and during many periods. It would be naive, however, to expect the system of centers, which has rapidly grown in scope and complexity, to sustain the exceptional rates of return of the past, unless it responds with flexibility and vigor to opportunities presented by the new biotechnology and other advances in knowledge.

The early successes in wheat and rice sprang from a rich stock of knowledge that existed before the centers were formed. Pre-existing stocks of knowledge were less ample for many of the other crops that the centers now address, and the potential for increases in output of those crops is more modest because they tend to be grown in harsher environments.

If, as a consequence, future returns to research are lower, the enthusiasm of donors for the centers could slacken. On the other hand, creating unrealistic expectations could be equally unfortunate. Nor can it be presumed that all programs at all centers are planned, organized, and conducted optimally. Improvements could no doubt be made by reducing or eliminating some programs and expanding others, and changing the way some programs are operated. These matters are the responsibility of the CGIAR's Technical Advisory Committee, which regularly reviews the work of all centers.

As national systems become stronger, the centers' emphasis will likely shift from producing readily adopted technologies to supporting the generation of new technologies by national systems. And as this occurs, it will be less easy to use the spread of varieties as an indicator of the value of the centers. An effort should be made to estimate future impacts as precisely as possible despite the far-from-perfect understanding of the mechanisms of generation and diffusion of technological change.

Since research opportunities always exceed research funds, decisions are continually being made about the allocation of resources. Informed insight, experience, and accumulated knowledge have always formed the cornerstone of decisions about research funding. Quantitative estimates of possible future benefits can serve as additional elements in making decisions. They can help in the ranking of projects, suggest where shifts in emphasis might raise total returns, and indicate projects whose expected payoff is unattractively low.

A review of the broad sweep of expected results from the centers indicates that some impressive gains may be made, particularly in technologies that are applicable to large areas. At almost every center, if just one major project meets expectations, it will generate returns far exceeding the cost of the center. In fact, there are a few undertakings that, if any one is successful, will generate benefits greater than the present costs of the entire CGIAR system.

Six projects and their expected impact on production were analyzed in some detail: improvement of upland rice for favored areas of Latin America, biological control of cassava pests, aluminum tolerance in wheat, heat tolerance in wheat, downy mildew resistance in maize, and true potato seed. Even after conservatively estimating gains in productivity and attributing only a small share of those to the centers, expected annual rates of return range from 20 to 40 percent. The high prospective rates of return reflect the fact that the centers' work is applicable to broad areas, so even small advances in productivity have an impressive payoff.

The international centers of the CGIAR system: Emphases, core funds, staffing

A study of the international agricultural research centers

At its November 1983 meeting, the Consultative Group on International Agricultural Research approved a proposal for a study of the 13 international agricultural research centers. Support for the study, both financial and in kind, was provided by the World Bank, Sweden, the United States, the United Kingdom, France, the Federal Republic of Germany, Canada, the Netherlands, Australia, and the United Nations Development Programme. The study director, Jock R. Anderson, began work in February 1984. Other members of the study team were identified and hired as early as possible.

The study had one major objective: to determine the impact that the CGIAR centers have made on agriculture in the Third World. Two distinct aspects were identified: (a) the contribution that the centers have made by helping developing countries improve their own agricultural research capabilities, and (b) the contribution that the centers have made, directly or in collaboration with national programs, toward developing research innovations that facilitate the increase of food production.

Case studies in some two dozen developing countries were commissioned to gather information bearing on the first aspect. Those case studies, plus other sources of data or information, were the basis for judgments on the second. In addition a series of studies was conducted on particular activities through which the centers might be expected to have had an impact.

The reports. Three types of reports are being published: a main volume, individual study papers, and this summary. The main volume was prepared by the study team consisting of Jock Anderson, Robert Herdt, Carl Pray, Grant Scobie, and Hans Jahnke. It is based on papers drafted by members of the study team and Jack Hawkes, Brian Hardaker, Janice Jiggins, Michael Lipton, Richard Longhurst, V. Rajagopalan, P. K. Aiyasami, Paul Teng, David MacKenzie, Robert Brinkman, Michael Nelson, Robert Bell and colleagues, and Jake Halliday. This summary of the main report was prepared by Steven Breth.

The advisory committee. A committee consisting of Frank Press, chairman, Joachim Weniger, Jonah Kasembe, I. G. Patel, Sir Ralph Riley, Luis Crouch, and Yujiro Hayami advised on the conduct of the study. In January 1984, the committee met and agreed on the scope of the study and a general plan of work. In October 1984, it reviewed the progress and some of the early documents, revised plans for completion, and drafted a preliminary report for the meeting of the Consultative Group in November 1984. In July 1985, the committee reviewed drafts of the main report and its summary, and advised the study director on preparation of the final documents. At its final meeting, the committee also had the benefit of a commentary prepared by a panel of independent authorities from the developing countries: Farzam Arbab, Martin Pineiro, Phillip Chigaru, S. W. Sadikin, Jonah Kasembe, and Francis Idachaba.

CGIAR Secretariat • Consultative Group on International Agricultural Research • World Bank • Washington, D.C. 20433 • USA—1985