International Agricultural Research

The new network of centers is designed to extend the Green Revolution to all the major crops of the Third World.

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The international network of agricultural research centers has nearly completed the first phase of its growth. The major food commodities and climatic zones of the Third World have now been brought under study. The sponsors of the network await a continuation and extension of the work that spearheaded the Green Revolution, the development of high-yielding varieties of wheat in Mexico and of rice in the Philippines. Notwithstanding the assured tones in some of the network's public documents, that is going to be a hard act to follow. Yet there are excellent prospects for gains which are less dramatic but which, over time, will make a major difference to the world's food supply.

The rapid growth of the network has been made possible by its unique organization and successful access to funds. It is supported by an international group of donors under the aegis of the World Bank in Washington, D.C. The history of the network can be briefly told. The prototype of its centers is CIMMYT (International Center for the Improvement of Maize and Wheat), the Mexican institute where Norman Borlaug developed his dwarf wheats. CIMMYT and its predecessor had been supported by the Rockefeller Foundation since 1943. Encouraged by CIMMYT's success, the Rockefeller joined the Ford Foundation in setting up the International Rice Research Institute (IRRI) in the Philippines.

Within a few years of its founding in 1960 IRRI came through with high-yielding strains of rice, and the two foundations started to plan other institutes. The Ford Foundation laid the groundwork for IITA (International Institute of Tropical Agriculture) in Nigeria and partnered the Rockefeller in founding CIAT (International Center for Tropical Agriculture) in Colombia.

By the late 1960's the burden of supporting the centers at the desired rate of growth had become too great for the foundations to bear alone. They turned to the World Bank, whose president, Robert S. McNamara, is a member of the Ford Foundation's board. McNamara set up a consortium of 15 potential donors, who met in 1971 and elected to inherit from Rockefeller and Ford the mantle of leadership for the Green Revolution.

Since then, progress in extending the network has been remarkably rapid. CIP, the International Potato Center, has been established in Peru. Last January ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) had its foundation stone laid in Hyderabad by Prime Minister Indira Gandhi. Two livestock centers are being set up in Africa—ILRAD (International Laboratory for Research on Animal Disease) in Nairobi, Kenya, and ILCA (International Livestock Center for Africa) in Ethiopia. Planning is under way for a Middle East crops research center to be based in Lebanon. The IBPGR (International Board for Plant Genetic Resources) has been established to conserve crop germ plasm. And the group has taken under its wing a rice testing organization known as WARDA, the West African Rice Development Association. No more centers are planned for the time being, although the Asian Vegetable Research and Development Center in Taiwan would probably join the network if a satisfactory political formula could be worked out.

The present network employs some 200 professional staff. The donors now include 14 nations in addition to the Rockefeller and Ford foundations (*1*). Contributions to the network have grown from about $15 million in 1972 to $23 million in 1973, $34 million in 1974, and a projected $48 million this year. This donors' organization is known as the Consultative Group on International Agricultural Research (CGIAR). Its chairman and secretariat are provided by the World Bank and it is sponsored by the Bank, the United Nations Development Programme, and the Food and Agriculture Organization.

In setting research priorities for the network the Consultative Group is guided by the Technical Advisory Committee (TAC), which consists of 12 members (six each from the developed and the less developed countries) and a chairman. Ten of the members are scientists; three, including the chairman, are agricultural economists.

TAC's chairman is Sir John Crawford, a former vice-chancellor of the Australian National University and one of McNamara's principal advisers on agriculture and rural development, particularly in India and Iran.

Scientific direction of the international network resides primarily with TAC, although the Consultative Group is free to reject TAC's advice and has done so on at least one occasion. (It turned down TAC's proposal for a food policy research institute, which is now to be funded by the Rockefeller and Ford foundations independently.) The Consultative Group generally operates by consensus, not votes. The only issue on which there has been a show of hands was whether to accept WARDA. Informally, the Rockefeller and Ford foundations still exert considerable influence on the operation of the network. All but one of the center directors are foundation-trained men, and there is a steady interchange of staff between the foundations and centers. The center directors are answerable to their boards of trustees, to an annual scientific and budgetary review by the Consultative Group, and to an in-depth scientific review by TAC every 5 years. Roughly 85 percent of their budget is provided through CGIAR by the donors, each of which contributes various sums to the centers of its choice. The World Bank, as residual donor, makes up any difference between the net contributions to a center and its agreed CGIAR-derived or "core" budget. Cen-

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ters acquire the rest of their support from donors on a bilateral basis. The extra funds are usually for "special projects" in which a donor may have some particular interest. The special project mechanism also affords center directors an alternative source of support for projects which they think the CGIAR may not wish to finance.

Overall, the directors work under considerably less red tape than most international bureaucracies engender. They seem to enjoy a healthy degree of autonomy, and cost has so far been no serious impediment to their plans.

With the exception of CIMMYT and IRRI, which have already proved themselves, the centers are all too young to be judged by their scientific output. It is by no means obvious that the successes of CIMMYT and IRRI will be easy to repeat. The new centers are tackling different problems, with different leadership and under conditions that may be less conducive to scientific discovery. Nonetheless, no miracle varieties are required to justify their existence. If they increase the productivity of one major crop by a few percent the centers will repay their investment, and the neglected state of most staple food crops offers the opportunity of doing considerably better that that. For example, the work of the international centers is estimated to have increased the value of the 1972–1973 wheat and rice crop in Asia by about $1 billion (*2*).

The salient features of the international network, shown in Table 1, indicate the ambit and ambition of the enterprise. Following are examples of some of the main projects being undertaken at the various centers.

IITA. With operations virtually suspended during the Nigerian civil war, IITA has now cleared the forest land donated to it and laid out fields. Of its four research programs (see Table 1), the most successful has been the improvement of grain legumes, particularly cowpeas. From its germ plasm collection, the world's largest, IITA has produced crosses that yield up to a third more than the best of the local varieties. Resistance to a number of diseases has been combined into single lines, which require pesticide to be applied only twice a season instead of ten times.

In the root and tuber program, some progress has been made with cassava. Lines have been developed which yield 50 tons per hectare in test plots, compared with the 20 tons yielded by the best local variety. The IITA team is also trying to reduce the bitterness of cassava by breeding for low cyanide content. Sweet potatoes make a good dry season crop but are susceptible to weevils; a large screening program has turned up some resistance to this pest.

CIAT. CIAT is the South American analog of IITA, specializing in beef, four crops, and farming systems. Cassava is one of its crops and, like IITA, the center has obtained yields of up to nearly 50 tons per hectare in experimental plots. CIAT has identified sources of resistance to bacterial blight and to thrips, but so far has not found cassava plants that respond to fertilizer.

CIAT has a major responsibility for field beans (*Phaseolus vulgaris*), an important protein source. The center can now produce beans with yields up to five times the national average. The gain is largely due to cleaning the seed, through which half the important diseases of beans are transmitted. The center helped clean seed for 80 farmers in Guatemala, who produced yields three times greater than before.

Half of Latin America's 250 million cattle are raised in the lowland tropics (CIAT's area of responsibility) and most take as long as 5 years to reach market weight. The center has been trying to improve weight gain by growing different forage crops in place of the native grasses. The best system developed so far is to grow molasses grass in the wet season and a legume (*Stylosanthes guyanensis*) in the dry. CIAT believes a liveweight gain of 150 to 200 kilograms per hectare can be produced on this system, compared with a gain of 20 to 30 kilograms on native grasses (*3*).

ICRISAT. The center's potential beneficiaries are the 400 million inhabitants of the semiarid tropics. Its responsibilities are worldwide and include the Sahel as well as India. Unlike IITA, ICRISAT was founded in a populated area, and several hundred farming families had to be moved. The center's $17-million building is not yet completed, but staff working from temporary quarters have had experimental crops in the ground since 1973.

ICRISAT is responsible for two important cereals, sorghum and pearl millet, and two pulses, pigeon peas and chick-peas. TAC recently assigned a fifth crop, groundnuts, to the center.

Work is progressing with two lysine-rich sorghums identified by Purdue University, West Lafayette, Indiana. The average yield of pigeon peas, an important crop in India, is about 600 kilograms per hectare, whereas the potential yield is nearer to 5000 kilograms. Maturation time is 300 days, but in experimental plots can be reduced to 150. There is considerable room for improvement both with this crop and with chick-peas, the leading pulse crop in India, but ICRISAT has not yet had time to breed more than its first few generations of crops.

In its farming systems program, the center aims to develop labor intensive rather than capital intensive technology. It has already designed bullock-drawn implements for ridging and fertilizer application.

CIP. Potatoes are the world's most important crop after rice, wheat, and maize, and can produce more protein per hectare than the cereals. But potatoes are not much grown in the tropics because of problems with disease, parasites, and storage. One of CIP's major objectives is to remove or reduce these constraints. Another is the collection of germ plasm. About 1000 varieties were donated by the Peruvian Ministry of Agriculture, and CIP expeditions have added 5000 more. Other thrusts include the search for genetic resistance to the fungi, bacteria, viruses, and nematodes.

ILRAD. The center is concerned not directly with production but with the major diseases of livestock, of which it has elected to concentrate on two, trypanosomiasis and theileriasis. The first disease, caused by a protozoan spread by the tsetse fly, is prevalent in vast stretches of land south of the Sahara, which could otherwise support an estimated 200 million cattle. Theileriasis, a major form of which is known as east coast fever, is another protozoan, blood-borne disease, but is spread by a tick. ILRAD is in the process of putting up buildings, which are to cost $4 million to $5 million by the time they are finished in 1978, and looking for a new director.

ILCA. The center's purpose is to increase production of tropical Africa's 130 million cattle, 100 million sheep, and 80 million goats. It is still in the process of devising its research strategy, collecting a library, hiring staff, and planning its buildings, which are expected to be completed in 1978 at a cost of more than $5 million.

WARDA. West African nations find themselves having to import increasing

amounts of rice, which last year cost them $140 million in foreign exchange. The countries involved established WARDA to conduct trials of rice varieties with the aim of raising production and reaching self-sufficiency. WARDA does not attempt to develop new varieties itself. The association has been accepted by the Consultative Group as a member of the international network.

IBPGR. The purpose of the board is to offset the steady worldwide erosion of plant genes by encouraging the development of seed collections. Creation of the board was recommended by a TAC working group chaired by the Australian Sir Otto Frankel, a longtime student of the problem. The board is chaired by Richard H. Demuth, a Washington attorney who is a former chairman of CGIAR. It has 13 scientists as members, who met for the first time last June. The board will undertake no research itself. Its job is to identify the priority needs for the collection of plant genetic resources, particularly those of significant economic importance. It will support existing collection programs, and recommend the establishment of new collections where necessary.

The board has ordered the creation of an international documentation system which will allow breeders anywhere in the world to determine if the germ plasm they need is available. It is sponsoring a symposium on wheat to encourage greater exchange of germ plasm between major national collections, particularly those of the United States and the Soviet Union.

ICARDA. A Middle East Research Institute has been recommended by TAC but not yet approved by CGIAR. The proposal faces the political problem that some of CGIAR's donors may be unwilling to support a center that the oil-rich countries could fund themselves. But the center will be sited in Lebanon, which has no oil, and oil-rich countries are being encouraged to join CGIAR on the same basis as other donors.

IRRI. IRRI has not significantly improved on rice yields since the release of its first high-yielding variety, IR-8. What it has done is to improve on resistance. One of its latest lines, IR-2061, is at least moderately resistant to about six or seven of the major insect and disease pests. The same line also matures quickly, which will be valuable in trying to grow one or more crops

Table 1. Present structure of the international agricultural research network.

Center	Location	Research	Coverage	Date of initiation	Proposed budget for 1975 ($000) (7)
IRRI (International Rice Research Institute)	Los Banos, Philippines	Rice under irrigation; multiple cropping systems; upland rice	Worldwide, special emphasis in Asia	1959	8,520
CIMMYT (International Center for the Improvement of Maize and Wheat)	El Batan, Mexico	Wheat (also triticale, barley); maize	Worldwide	1964	6,834
CIAT (International Center (for Tropical Agriculture)	Palmira, Colombia	Beef; cassava; field beans; farming systems; swine (minor); maize and rice (regional relay stations to CIMMYT and IRRI)	Worldwide in lowland tropics, special emphasis in Latin America	1968	5,828
IITA (International Institute of Tropical Agriculture)	Ibadan, Nigeria	Farming systems; cereals (rice and maize as regional relay stations for IRRI and CIMMYT); grain legume (cowpeas, soybeans, lima beans, pigeon peas); root and tuber crops (cassava, sweet potatoes, yams)	Worldwide in lowland tropics, special emphasis in Africa	1965	7,746
CIP (International Potato Center)	Lima, Peru	Potatoes (for both tropics and temperate regions)	Worldwide including linkages with developed countries	1972	2,403
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	Hyderabad, India	Sorghum; pearl millet; pigeon peas; chick-peas; farming systems; groundnuts	Worlwide, special emphasis on dry semi-arid tropics, nonirrigated farming. Special relay stations in Africa under negotiation	1972	10,250
ILRAD (International Laboratory for Research on Animal Diseases)	Nairobi, Kenya	Trypanosomiasis; theileriasis (mainly east coast fever)	Africa	1974	2,170
ILCA (International Livestock Center for Africa)	Addis Ababa, Ethiopia	Livestock production systems	Major ecological regions in tropical zones of Africa	1974	1,885
IBPGR (International Board for Plant Genetic Resources)	FAO, Rome, Italy	Conservation of plant genetic material with special reference to cereals	Worldwide	1973	555
WARDA (West African Rice Development Association)	Monrovia, Liberia	Regional cooperative effort in adaptive rice research among 13 nations with IITA and IRRI support	West Africa	1971	575
ICARDA (International Center for Agricultural Research in Dry Areas)	Lebanon	Probably a center or centers for crop and mixed farming systems research, with a focus on sheep, barley, wheat, and lentils	Worldwide, emphasis on the semi-arid winter rainfall zone		

after the first rice crop. Other goals being pursued at IRRI include genes for greater protein content and an elongation gene which enables the plant to grow taller if the field water level rises.

IRRI's rice germ plasm bank now totals 30,000 accessions, with recent samples being chosen for their tolerance to poor conditions, such as saline or acid soil, cold, or deep water. IRRI has not yet found an absolutely safe place in which to store its invaluable collection, a circumstance of possible interest to the IBPGR.

A relatively new direction is the development of cropping systems. When peanuts are grown with corn, for example, attacks by corn borers are much reduced, apparently because peanuts attract a spider that preys on the borers. IRRI has also found that rice and corn can be profitably intercropped, the value of a combined crop being about 50 percent greater than that of either crop grown separately.

Agricultural machinery is another of IRRI's interests, with emphasis on machines that can be built locally and increase harvests without displacing labor. A small 5-horsepower tiller is selling well in the Philippines. Another device is a grain dryer which instead of oil uses last year's rice hulls as fuel.

IRRI puts considerable effort into education, and has clocked up some 800 man-years of training since 1962. Courses range from academic programs to teaching trainers how to give rice production training courses in their own countries.

CIMMYT. The Mexican center has developed its own worldwide network for testing the products of its breeding programs. In 1973 its wheats were grown at 1140 sites in 66 countries and its maize (corn) varieties at 289 sites in 48 countries.

A major new development in wheat is the creation of "multilines." Wheat's major enemy is the rusts, 10 years apparently being the longest a standard variety can withstand attack. Multilines are mechanical mixtures of seeds which bear different genetic resistances to rust. When one of the components becomes susceptible to rust it can be replaced, and meanwhile the farmer gets a satisfactory harvest from the part of the crop that is still immune.

A major thrust with maize has been to overcome the various disadvantages incurred by introducing the "opaque-2" gene, which confers a high content of lysine. The reason for persisting with this uphill task is that acceptable high-lysine varieties could double the digestible protein content of the world's maize, only half of which can be digested today because of an improper balance of amino acids. CIMMYT's breeders have remedied the defects of low yield and fungus susceptibility but still have more to do on the consumer acceptability of opaque-2 maize.

Another genetic grind which CIMMYT seems near to bringing off is to make a viable crop of triticale, the cross between wheat and rye. Triticale protein is superior to wheat's in both quality and quantity. CIMMYT has hauled up the yield of triticale from 2 or 3 tons per hectare in 1969 to 9 tons in the most recent crop. Trials are being held in 40 countries. If and when these are successful, CIMMYT will have created the first new cereal crop since the Neolithic.

The broad scope of the issues being tackled by the various centers gives some idea of the promise of the international network and the reasons for its sponsors' confidence. There are, of course, a number of problems ahead. One is the danger that the network may become victim of its own success. Not all the centers will produce equivalents of CIMMYT's wheats. CIMMYT's maize program, which for years produced unspectacular results, is just as likely to be the model which the other crop programs will follow. (Even the wheat has had its share of disasters—in 1972 Brazil lost half its national crop when the wheat was attacked by a non-Mexican disease it had not been bred to withstand.) Will the donor members of the Consultative Group be prepared to wait for long-term payoffs if the network's outstanding early successes cannot be equaled?

Cost has been no object in the design of the second generation of centers, but big buildings, air-conditioned laboratories, and international-scale salaries were not the conditions in which Borlaug acquired his intimate knowledge of farmers' needs. Nor has TAC yet had time to prove its leadership. As one participant (*4*) observed at a recent conference on the network: "Institution building requires a high degree of imagination and a willingness to protect research scientists from outside demands. It is instructive to note here that CIMMYT was supported only by the Rockefeller Foundation in its formative years. Most other international organizations were not capable then, and are not capable now, of the imaginative leadership demonstrated by RF in those days."

The adequate supply of funds has meant that the centers have not yet had to compete seriously with each other for resources. Frictions seem already to have been engendered by the divided responsibility for certain crops. CIMMYT, for instance, is required by its trustees to improve maize on a worldwide basis, IITA and CIAT to improve it on a regional basis. The same situation exists between the latter two centers and IRRI over rice. Cooperation has so far been voluntary but the results, according to CIMMYT's director (*5*), "have not been satisfactory (in CIMMYT's judgment) to any of the centers, or trustees or donors." It is not yet clear how TAC intends to arbitrate these issues.

Perhaps the most refractory problem the network faces is that of the national research systems in the countries the centers are trying to help. The national systems are a crucial link in adapting the fruits of the network's research to local conditions and encouraging their adoption by farmers. But the generally poor quality of most national systems is a formidable constraint to the full realization of the network's efforts. According to CIMMYT's director (*5*), for example, crop scientists in the less developed countries are often driven to leave because of "low salaries, staff promotion on political rather than merit basis, lack of budget support from policy makers, corruption, and many other grievances." And the director of IRRI (*6*) notes that in some cases governmental restrictions and inflexibilities "provide almost insurmountable roadblocks to the development of viable agricultural research programs irrespective of the external support provided."

The question facing the international centers is how far they can or should attempt to remedy such defects. Matters of land tenure, for example, are obviously beyond their competence. But both CIMMYT and IRRI have invested so much effort in training programs designed to strengthen national systems that they have, in effect, ceased to be pure research institutes and have evolved into research-based institutes of agricultural development. TAC itself seems to be ambivalent as to whether it could become an agent for strengthening national research systems.

Perceptions of the seriousness of the

world food situation have fluctuated widely and frequently over the last decade, but those in the network community have never had much doubt of the importance of their work. TAC chairman Crawford referred recently to the "Malthusian situation in which the world finds itself" with the comment that "At best, TAC believes research will buy time while population is brought under control." Many reject the extreme pessimism of the Malthusian view, yet when they do so it is almost always with the expectation that the few hundred people who staff the international centers will deliver what is expected of them.

References and Notes

1. For calendar year 1974 the donors and their contributions (in $000) were: United States (7000), Canada (4685), World Bank (3200), Rockefeller Foundation (3100), Ford Foundation (3000), Germany (2845), Britain (2015), Interamerican Development Bank, Washington, D.C. (2000), Sweden (1625), United Nations Development Programme (1450), International Development Research Center, Ottawa (930), Netherlands (605), Norway (430), Belgium (390), Denmark (370), Switzerland (290), Kellogg Foundation (280), Japan (270), France (125), and Australia (100). New donors in 1975 will include Nigeria and the United Nations Environment Programme.
2. D. G. Dalrymple, "Impact of the international institutes on crop production," paper given at the Airlie House symposium, January 1975, on international agricultural research, organized by the Agricultural Development Council, 630 Fifth Avenue, New York 10020. The ADC will have a conference summary prepared within a few months, and may later issue the proceedings as a book.
3. U. J. Grant, director of CIAT, presentation at International Centers' Week 1974, Washington, D.C. The directors' presentations are the main source of the notes on the various individual centers.
4. R. E. Evenson, "Comparative evidence on returns to investment in national and international research institutions," paper given at the Airlie House symposium.
5. H. Hanson, "Articulation of the international and national systems; the CIMMYT outreach program," paper given at the Airlie House symposium.
6. N. Brady, "Articulation of the international and national systems: the IRRI outreach program," paper given at the Airlie House symposium.
7. Figures are for the centers' "core" budget, or request from CGIAR, and do not include bilateral funds, which constitute some 15 percent of the average center's budget. Totals for the first six centers, taken from Dalrymple (*2*), include other sources of funds, such as earned income, but exclude special project funds.

Food Science in Developing Countries

Norman L. Brown and E. R. Pariser

One of the earliest organized efforts to identify and quantify the food and nutrition problems of developing countries was the series of World Food Surveys that were conducted by the Food and Agriculture Organization (FAO) of the United Nations starting in 1946. A little later the United States began to conduct a series of even more comprehensive food surveys in developing countries under the aegis of the Interdepartmental Committee on Nutrition for National Defense (ICNND) (*1*).

In the following remarks, we will attempt to describe some aspects of the response by aid-donor countries and the United Nations to nutritional problems in the less developed countries as they are revealed in these and similar nutrition surveys and investigations; we will further suggest some possible answers to the questions that this response has raised, and we will finally urge that the different distinct and complex food systems that exist in both developing and industrialized communities should be investigated by in-depth social anthropological studies to enhance the chances for successful nutrition intervention.

Response of Aid Donors to Food Needs

The usefulness of these global and national food surveys should not be underestimated, despite the inherent risks in making generalizations from such vast and complex undertakings that deal with large and disparate populations, each with a variety of food habits. They provided, by and large, an adequate clinical picture of the spectrum of foods consumed by the people studied. The ICNND studies in particular do not seem to have suffered from cultural bias; the overwhelming majority of the team members were host-country nationals, and all foods and beverages—including snack foods—were included in their surveys. It is safe to say that the FAO surveys provided a much needed baseline for nutrition policies and nutrition planning programs of both the United Nations and individual countries, and the ICNND surveys provided valuable detailed statistics and data on specific nutrients, foods, food habits, nutritional status, and some indication of the steps needed to attack specific regional malnutrition problems.

Once the problems were identified, however, the response of the aid-donor countries and the U.N. agencies was generally culturally biased. The conventional approach to the food problems of developing countries was, and still largely is, seen through Western eyes, and as a consequence Western technology has had a serious influence upon these countries in at least three ways: one is in the kinds of foods distributed in emergency situations and for long-term food aid; the second is the way in which educational institutions determine the outlook of the food scientist or technologist who works on problems typical of developing countries; and finally there is the effect that the export of the Western model of agriculture and other food production techniques has had on food production.

Export of food products. Aside from food grains, the United States and other industrialized countries distribute products of Western food technology such as dried skim milk (DSM), corn-soy-milk (CSM) mixtures, wheat-soy blends (WSB), and Incaparina. These products are wholesome and nutritious, and if consumed as intended will provide the valuable high-quality protein required by the target populations for adequate growth, development, and maintenance (*2*). Nevertheless, they are not part of the traditional diets, and in the case of DSM, CSM, and

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