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9. ABSTRACT

The third section of papers from the Airlie House conference of 1975 is devoted to the international agricultural research institute system. The first paper (by J.G. Crawford) traces the development of a system for organizing, funding, and managing the new institutes, spearheaded by the Ford and Rockefeller foundations and now guided by the Consultative Group on International Agricultural Research (CGIAR). The programs that have been developed to achieve closer articulation of the research programs of the international and national systems are outlined by the director of IRRI (Nyle C. Brady) and the director of CIMMYT (Haldore Hanson). The problem of establishing effective working relationships between the international and national agricultural research systems is reviewed (by Sterling Wortman). The final paper (by Burton E. Swanson) presents a comparison of the impact of the IRRI and CIMMYT training programs on the career patterns and effectiveness of young scientists who have studied at these two programs.

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Resource Allocation and Productivity in National and International Agricultural Research

Thomas M. Arndt
Dana G. Dalrymple
and
Vernon W. Ruttan
Editors

UNIVERSITY OF MINNESOTA PRESS, MINNEAPOLIS

Preface

Within the last decade significant steps have been taken to narrow the agricultural technology gap among countries. New international agricultural research centers have been established, and a number of developing countries have made substantial progress in strengthening their national agricultural research capacities. It is estimated that world expenditures on agricultural research (in constant 1971 U.S. dollars) have risen from approximately $1.3 billion in 1959 to $3.8 billion in 1971. In the less developed countries of Latin America, Africa, and Asia, the estimated increase in research expenditures for the same period was from $141 million to $957 million.

The creation of two international agricultural research institutes in the early 1960s was an important factor in this surge of research investment. The establishment of the International Rice Research Institute (IRRI) in the Philippines in 1960 and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico in 1966 signaled a wider contemporary refocusing on research as an essential instrument of agricultural productivity change in the less developed countries (LDC's).

The ensuing story is well known. CIMMYT and IRRI developed short-strawed, fertilizer-responsive, high-yielding wheat and rice varieties which were rapidly adapted and adopted in parts of Asia, Africa, and Latin America and which produced an upsurge in grain production popularly known as the "green revolution." By 1975, nine international research institutes and two other international programs were either in operation or in the process of being established in the LDC's (see Table 11-1).

The view that effective research capacity in developing countries is a primary means to raising agricultural productivity is now widely shared. The World Bank, the United States Agency for International Development (USAID), and other donors have begun to give agricultural research a higher priority for assistance. Investment in agricultural research in developing countries has grown rapidly in recent years. As the agricultural research system has continued to expand, research productivity and research resource allocation have become important issues for development planners and science managers.

In order to examine these issues, an international conference was held at Airlie House, Virginia, in January 1975. The conference had two main objectives: to examine recent evidence on the returns to investment in national and international agricultural research systems; and to explore the relevance of social and economic factors for the organization and management of national and international research systems. Technical issues related to the measurement of research productivity, the planning of research programs, and the management of research systems were also discussed.

The conference drew together over fifty natural scientists, social scientists, and administrators from national and international research agencies, some of whom wore more than one hat. The format of the conference was somewhat unusual. Individual papers were not read but rather circulated before the meeting and orally summarized at the conference by presiected discussants, several of whose commentaries proved so stimulating and original that they are included in this volume (chapters 26 and 27). Most of the conference, therefore, was devoted to what turned out to be a rich and vigorous discussion.

Following the conference, contributors were asked to review and revise their papers in the light of the discussions. The revised papers were then edited and returned to the authors for their further review, a painstaking process which was completed in November 1975. As they appear in this book, the twenty-eight papers have been organized into six sections. They are preceded by an introduction (by Thomas M. Arndt and Vernon W. Ruttan) which highlights the main issues discussed at the conference.

The first section of this book is devoted to a series of studies of the *productivity of national research systems* in both developed and less developed countries. There are two papers on the organization and productivity of research systems in developed countries: the first (by Yujiro Hayami and Masakatsu Akino) describes the national-prefectural system in Japan; the second (by Willis L. Peterson and Joseph C. Fitzharris) discusses the federal-state system in the United States. There are also two papers on returns to investment in agricultural research in developing countries, one drawing upon Colombian experience (by Reed Hertford, Jorge Ardila, Andrés Rocha, and Carlos Trujillo) and one focusing upon India (by A. S. Kahlon, P. N. Saxena, H. K. Bal, and Dayanath Jha). The final paper in this section (by Reed Hertford and

Andrew Schmitz), prepared after the conference, reviews some of the theoretical foundations of, and empirical considerations involved in, the evaluation of returns to research.

The second section includes three papers on the *productivity of international research systems*. The first paper (by Dana G. Dalrymple) documents the impact of the CIMMYT and IRRI varietal development programs on wheat and rice production in Asia. A second paper (by Robert E. Evenson) reviews the history of cycles in research productivity and in international diffusion patterns for three commodities: sugarcane, wheat, and rice. A third paper (also by Evenson) presents measures of the rates of return to the resources invested in research at IRRI and CIMMYT. In a fourth paper (by Yoav Kislev) an attempt is made to develop a theoretical model of applied research consistent with the historical experience reviewed in the earlier papers in the first two sections.

The third section is devoted to the *organization and development of the international agricultural research institute system*. The first chapter (by J. G. Crawford) traces the development of a system for organizing, funding, and managing the new institutes, spearheaded by the Ford and Rockefeller foundations and now guided by the Consultative Group on International Agricultural Research. The programs that have been developed to achieve closer articulation of the research programs of the international and national systems are outlined by the director of IRRI (Nyle C. Brady) and the director of CIMMYT (Haldore Hanson). The problem of establishing effective working relationships between the international and national agricultural research systems is then reviewed (by Sterling Wortman). The final paper in this section (by Burton E. Swanson) presents a comparison of the impact of the IRRI and CIMMYT training programs on the career patterns and effectiveness of young scientists who have studied at these two institutes.

The fourth section is devoted to issues bearing directly on the *organization and management of agricultural research systems*. The first paper (by Albert H. Moseman) outlines the evolution of coordinated national research projects for improving food crop production. Two papers focus on the problem of reorganizing and reforming national research systems: in the United Kingdom (by Tilo L. V. Ulbricht) and in Brazil (by José Pastore and Eliseu R. A. Alves). Next, the contribution of private sector international agricultural research is described (by S. M. Sehgal), based on the experience of Pioneer Hi Bred International. A systems approach to research resource allocation is then outlined and evaluated (by Per Pinstrup-Andersen and David Franklin). The final chapter in this section (by C. Richard Shumway) presents a review and evaluation of the literature on formal models and methods for allocating resources in research.

The fifth section examines the role of *economic and social factors in re-*

search resource allocations. The first paper (by Martin E. Abel and Delane E. Welsch) outlines a theoretical model for exploring the relative effects of environmental constraints and commodity mix on research resource allocation. The second paper (by John W. Mellor) is devoted to an empirical evaluation of the effects of efforts to relate research resource allocation to alternative goals such as labor absorption. In a third paper (by J. P. Ramalho de Castro and G. Edward Schuh) the use of an economic model to establish research priorities, based on Brazilian data, is illustrated. The role of resource endowments and relative prices in inducing the choice of alternative paths of technical change — that is, labor saving versus land saving — is documented (by Hans P. Binswanger). The final paper in this section (by Alain de Janvry) presents a theoretical model of dialectical interaction between technical and institutional change in agriculture which suggests important directions for future research.

The final section is devoted to discussion of the research strategy and management issues that will affect *the future of the international research system* and the productivity of national research systems. The first paper (by A. T. Mosher) is devoted to a discussion of unresolved issues in the evaluation of the international system. A second essay (by Theodore W. Schultz) focuses on the role of economic policy in influencing the prospects for gains from agricultural research. In the final paper (by J. G. Crawford) the policies and problems facing the Consultative Group on International Agricultural Research and its Technical Advisory Committee in their efforts to strengthen national and international research are reviewed.

The papers included in this volume cannot, of course, reflect fully the excitement and challenge of the Airlie House conference. Particularly significant contributions to the discussions were made also by Richard Baldwin of Cargill Inc.; Joel Bernstein of the U.S. Agency for International Development; John K. Coulter of the Consultative Group on International Agricultural Research; George Darnell, James M. Fransen, Raj Krishna, and Montague Yudelman of the World Bank; M. McDonald Dow of the National Academy of Sciences; Walter L. Fishel of the U.S. Department of Agriculture; Lowell S. Hardin of the Ford Foundation; W. David Hopper of the International Development Research Centre; Richard Nelson of Yale University; Peter Oram of the Food and Agriculture Organization of the United Nations; S. J. Webster of the Ministry of Overseas Development of the United Kingdom; A. M. Weisblat of the Agricultural Development Council, Inc.; and F. R. Wittnebert of the Parker Pen Co.

The Airlie House conference was given considerable impetus and background by the materials presented and discussed at an earlier symposium on Resource Allocation in Agricultural Research held at the University of Minne-

sota in February 1969. The results of the Minnesota conference, which focused on many of the same issues considered at Airlie House but from a domestic (United States) viewpoint, were published in a book edited by Walter L. Fishel and entitled *Resource Allocation in Agricultural Research* (Minneapolis: University of Minnesota Press, 1971).

Both the Minnesota and Airlie House conferences were oriented to formal research carried out at nonprofit institutions and supported primarily with public or philanthropic funds and, to a lesser extent, to research conducted by private firms. It is recognized, however, that significant technical improvements may also result from informal research by farmers themselves or by small, local firms. Simple selection of improved varieties of seeds has traditionally been an important source of varietal development and yield increase. In the field of mechanical technology, simple but effective mechanical devices invented by farmers or mechanics, such as small irrigation and cultivation equipment, continue to provide many of the models for equipment engineered, manufactured, and marketed by larger firms. The work of both national and international research programs in many cases builds on this indigenous technology. Thus while little is said about informal research in this volume, its potential importance should not go unrecognized.

The structure of public agricultural research differs somewhat between the developed and the less developed nations. In the developed countries, research is conducted both by ministries (or departments) of agriculture and by colleges and universities. In the developing nations, research has traditionally been much more strongly concentrated in specialized arms of the ministries of agriculture or in autonomous, commodity-oriented research institutes. Colleges of agriculture in developing countries have usually concentrated on teaching, although in some cases they have done significant research (the popular rice variety C4-63, for instance, was developed by the College of Agriculture at the University of the Philippines) and may well play a larger role in the future. A paper on "Articulation of the International System with Other Regional Organizations: Ministry and University," by Jose Drilon was originally scheduled for the conference, but unfortunately Dr. Drilon, for reasons beyond his control, was unable to prepare the paper or to participate in the discussions.

We would also like to emphasize that, while this volume focuses on the importance of improved technology in the process of agricultural development, we are quite aware that it is not the only factor. A host of other forces—social, institutional, economic, and technical—both influence the adoption of technology and set the stage for the complex of other changes which must take place in the process of agricultural and economic development. Although improved technology may be the key factor in some societies, in others it may

not. Improved technology alone is clearly not tantamount to agricultural development. But if the proper forms of technology can be efficiently generated through research, the development process can often be facilitated. It is our hope that this volume will contribute to a better understanding of the role of research in the process of technical change and of the role of technical change in agricultural development.

The conduct of the Airlie House conference and the preparation of this volume have been possible only through the help of many individuals and several institutions. The conference planning committee consisted of Robert E. Evenson, Walter L. Fishel, and Vernon W. Ruttan. The conference was sponsored by the Agricultural Development Council under its Research and Training Network Program, a program which, in turn, is funded under a contract with the United States Agency for International Development. Additional support for international participation in the conference was provided by the World Bank.

Turning a set of conference papers by an international cast into a book is, as we learned, far from a quick or simple job. Our task was facilitated by the cooperation and forbearance of the individual authors, most of whom found their carefully revised papers further edited and trimmed. Virginia O. Locke played a key role in the copy editing; her professional skills and contributions were of great assistance. We would also like to express our appreciation to Willis L. Peterson for his review of technical portions of the final page proofs and to Raymond D. Vlasin for his very helpful review and evaluation of a preliminary draft of the conference proceedings manuscript.

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T. M. Arndt, D. G. Dalrymple, and V. W. Ruttan

11

Development of the International Agricultural Research System[1]

J. G. Crawford

This chapter is about international agricultural research and, more especially, developments since May 1971. In that month the first meeting of the Consultative Group on International Agricultural Research (CGIAR) was held. The membership comprised the sponsors, which included the World Bank (IBRD), the Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP), and fifteen additional members – nine national governments, two regional banks, three foundations (Rockefeller, Ford, and Kellogg) and the very young International Development Research Centre (IDRC) of Canada. (See Appendix 11-1 for a complete listing of the membership.)

The Consultative Group had met informally in January 1971 following continuing talks between the Ford and Rockefeller foundations, IBRD, FAO, and UNDP since October 1969. The leadership was provided by the World Bank, which now provides the chairman and secretariat of the group. The May meeting adopted a number of objectives (see Appendix 11-2) designed to strengthen existing international research in Mexico (CIMMYT), the Philippines (IRRI), Latin America (CIAT), and West Africa (IITA), and to develop new activities to meet priority needs as determined by the Consultative Group.[2]

The impetus for this action was the desire to encourage more research to assist developing nations increase the quantity and improve the quality of

Table 11-1. International Agricultural Research System in 1975

Center	Location	Research	Coverage	Date of initiation	Proposed budget for 1975 ($000)
IRRI (International Rice Research Institute)	Los Baños, 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; cassav. ield 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) Maintaining fertility in humid tropics	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

Table 11-1 – continued

Center	Location	Research	Coverage	Date of initiation	Proposed budget for 1975 ($000)
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	Hyderabad, India	Sorghum; pearl millet; pigeon peas; chick-peas; farming systems; groundnuts	Worldwide, special emphasis on dry semiarid 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 semiarid winter rainfall zone		

their agricultural output and thus to raise standards of living. All parties realized that increased agricultural productivity was essential to economic and social development in the great majority of these countries.

Additionally, the two foundations which had initiated the research centers had indicated that the future needs of these and other new centers would be beyond their financial capacity. They indicated continuing strong support but nevertheless felt the need, in the unofficial words of one senior official, of "going public." I believe the step the foundations took will be given a high and honorable place in the history and achievements of international cooperation.

From this beginning, the international research system has grown in breadth and complexity. It now comprises eleven centers, located in Asia, Africa, Latin America, and Europe, which are involved in varied research programs, as can been seen in Table 11-1. An additional center in the Middle East is being planned.

From a cost of about U.S. $12 to 14 million in 1972, the program financed by the Consultative Group was close to $34 million in 1974 (capital, core budget, and outreach programs) with a commitment of about $45 million for 1975. While an element of this increase is attributable to inflation, it does represent a growth from four centers in 1971 to nine in 1975. In a short period of three years, the CGIAR system has given solid evidence of its willingness and ability to back its judgment that international research has a vital role to play.

The Technical Advisory Committee

To assist it in its work, the Consultative Group established in May 1971 the Technical Advisory Committee (TAC) of which I have the honor to be chairman. It comprises twelve scientists and me. (See Appendix 11-3 for a list of members.) FAO provides the secretariat. Put in a sentence, the task of TAC is to define priorities for research and to recommend action.

TAC may either act on its own initiative or consider proposals submitted from the Consultative Group through its sponsors. (See Appendix 11-4 for TAC's full terms of reference.) It has to be remembered that the established four centers – IRRI, CIMMYT, CIAT, and IITA – had virtually preempted judgment on the matter of research priorities. While TAC had little difficulty in approving the main work of these bodies, it has begun to encourage some new thrusts, such as the move into rainfed rice production by IRRI.

The work of TAC is explicitly related to the problems of developing countries both in technical (agricultural) and socioeconomic fields. National research in developed countries is often highly relevant but is of formal concern

to TAC only when it is or can be linked with the problems of developing countries.

TAC has defined "international research" broadly to mean "research which, although based in one country, is of wider concern, regionally or globally; is independent of national interest and government control; and retains appropriate links with national and other regional or international research systems to ensure the necessary testing of results and feedback of both results and needs."

TAC is advisory only: the Consultative Group will not act on important research proposals without prior advice from TAC, but it remains free to reject or modify the advice it receives. It follows that the Consultative Group has to be persuaded by TAC in its development of ideas on priorities.

Priorities and Programs

TAC, confirmed by the Consultative Group, places the highest importance on research directed toward increasing the amount and quality of food produced. This is hardly surprising in the Malthusian situation in which much of the world finds itself. At best, TAC believes, research will buy time while population growth is brought under control, but it is vital even for this purpose. This is reflected in TAC's statement on the cereals:

> In the first place cereals provide the mainstay of the diet in most developing countries, especially for the poorer people, supplying an average 52 percent of the calories and nearly half the total protein. It has been shown that if there is a serious deficit in calories in the diet the body consumes protein for energy. Since cereals generally make the largest single contribution of any commodity to both energy and protein, research to increase their yield and protein content is of crucial nutritional importance. Upgrading their amino-acid composition could, at no extra cost to consumers, make a further improvement in the quality of the diet. Secondly, despite the real successes in increasing wheat and rice output, cereal production in developing countries has barely kept pace with population *and* income growth during recent years, and experience in Asia in the last two years shows how fragile is the base on which these critical supplies rests. Income elasticity of demand for cereals is still high in the poorer countries, quite unlike the situation for food grains in the developed economies, and an important indication that food consumption levels are inadequate. In a number of countries failure to increase production rapidly enough to meet domestic demand has led to increasing imports, draining foreign exchange required for social and economic development. Third, cereals are the lynchpin of the cropping system in many developing countries and contribute signifi-

> cantly to income and employment. Finally, a faster growth of grain production will be necessary if feed supplies are to become available in sufficient quantity at prices which will permit their economic use in livestock rations. It is relevant to note the rapidly rising demand for feedgrains in the more affluent nations, which has been one factor contributing to the recent stringency and high prices of cereals and soya beans. This has in turn affected the availability of grains on concessional or normal trade terms to developing countries and further emphasizes the need to increase output in these countries as rapidly as possible.

The TAC report goes on to observe the growing necessity to raise yields per hectare as new arable land becomes more and more limited in relation to population. Its report comments:

> It thus becomes increasingly necessary to turn towards raising yields and crop intensities per acre as the major source of future growth, and since cereals occupy the largest share of the arable area in a wide range of environments, they hold the key to the more effective use of land and water resources. *Unless their yields can be increased or their time to maturity reduced, it will be correspondingly more difficult to make significant progress with other crops and livestock since more and more land will have to be devoted to satisfying basic calorie requirements.* The alternative – increasing imports – is open only to a few countries.

The main cereals supported are rice, wheat, barley, triticale, sorghum, and millet.

Turning from cereals to other key commodities, the TAC has accorded high priority to those which will improve the quality of the diet, especially in respect to protein. In particular, it has focused atttention on the food legumes and on ruminant livestock. (It recognizes fully the place of pigs and poultry, especially in developing their production by labor-intensive methods. Most members have felt that this would not require extensive research, but that the opportunities open for such development could be seized by the application of known methods of disease control, feeding, and management.) TAC is also supporting research in starchy foods including cassava, potatoes, yams, and sweet potatoes. The importance of these crops in many developing areas with poor resources in relation to population – as in tropical Africa – is very great indeed. TAC has yet to determine its position in respect of aquaculture but there is evidence of scope for research and training with definite promise of breakthrough.

TAC does recognize a second-level priority for food research. To quote its statement again:

> Having taken a firm position on its priorities for cereals, food legumes, roots and tubers, and ruminant livestock (especially cattle), and placed

> a temporary questionmark against aquaculture, the TAC has been less decisive on some other foods, in particular oilseeds, vegetables and tropical fruits. This is partly the result of pressure of work related to the commodities listed above, which, it decided in its earliest session, were of highest priority, and where some good projects were already in the pipeline, but it also reflects a lack of sound proposals for research in other food commodities.

This brings me to the important question of "nonfood," "industrial" or "agricultural raw materials" which have considerable importance in the economies of many developing countries. Cotton, jute, rubber, and forests are examples. Given the probable order of financial constraints, which I discuss later, TAC has been firm that it would be unhappy to give preference to research in these crops (to be supported by the Consultative Group) if this was likely to impair necessary programs of food research. TAC is willing to consider proposals for nonfood crops referred to it provided that "the overriding need to secure the staple food supplies of the mass of the people was first covered by existing or new international and regional research programmes."

Factor-Oriented Research and Systems Research

I have outlined our priorities in commodity terms. This at least has the merit of clarity and easy definition. Nevertheless, TAC has also had before it certain proposals for research relating to what might best be defined as factors of production – water use and management, fertilizers, integrated pest control, pesticide residues, etc. – which have caused it some difficult moments. TAC stated its position as follows:

> In general, members have taken the view that such problems are most meaningfully studied in relation to specific commodities rather than as ends in themselves. They have argued that one of the reasons for the success of the rice and wheat programmes has been the realisation by IRRI and CIMMYT of the need to develop and present to the farmer an integrated "package" of technology appropriate to their new varieties, and not just the latter in isolation unsupported by other essential inputs.
>
> While there is much merit in this argument, there are nevertheless instances which can be identified where it may be an inadequate approach and where it is essential to move from the study of the commodity or package of technology to that of the system. Except in monocultures, water use and management has to be related to the crop-mix rather than to the individual crop; fertiliser and pesticide residues contributing to environmental pollution again come from the totality of the farm

and not just one enterprise. The introduction of small-scale livestock often implies a major revision of an established system. Multiple cropping depending on high output per annum involves radically different management *and* plant breeding and cultural concepts than systems which depend principally on high yield per individual crop. Inadequate survey and exploration of surface and sub-surface water resources combined with insufficient research on soil/plant/water relationships is frequently a serious obstacle to sound design, good water management and the development of optimum production systems in irrigated areas. Storage, and control of certain causes of crop loss, e.g., rodents, may present problems of a broader nature than a single crop.

It is with these thoughts in mind that TAC has, of late, been stressing the scope for systems work which leads into socioeconomic research also. It is naturally concerned, within this framework, with devising means of intensifying agriculture as a means of raising total productivity (of two or more crops) per hectare through better resource utilization. In doing so, it may at times be forced to recognize a degree of location specificity not normally a constraint on commodity-oriented research. This in turn gives emphasis to regional and national research of the kind being considered in Africa (livestock management) and in the Middle East.

Despite the greater difficulty confronting TAC in looking at research in noncommodity-oriented terms, TAC is prepared to do so.[3] Its general position is summed as follows:

But although increasing yields and production of basic staple foods must remain a priority goal, the ultimate objective of agricultural research is development and the economic well-being of people. We must not be so bewitched with the hopes of further spectacular successes with single crops that we fail to recognize that other pathways to growth may exist. In some regions, for ecological, social, or economic reasons, research of a broader nature – even if it appears more complex, may offer the better hope of a solution. Where such an approach seems desirable the TAC and the Consultative Group must grasp the nettle boldly.

Socioeconomic Research

The very real problems of, and opportunities for success in, the green revolution have aroused widespread demands for a single international center in socioeconomic research. At the other extreme, many expect IRRI and CIMMYT to carry the whole burden of socioeconomic research associated with the national application of the rice and wheat technologies emerging from their work. Neither approach alone makes sense.

TAC has recognized three levels of action:

(i) *research at the micro-level* (farm or village community), to identify the socio-economic constraints to the successful adoption of new technology, and to guide scientists at the International Centres and elsewhere as to the types of technology most likely to be acceptable to farmers.

(ii) *research at the level of public policy*, e.g., to determine the measures and incentives needed to accelerate the use by farmers of technical innovations, to give early warnings of possible "second generation" effects of such innovations, e.g., on employment or prices, and to illuminate the choice of alternatives.

(iii) *research at the macro-level* on broad issues affecting more than one country, or the economy of a country as a whole, e.g., on commodities and trade, some aspects of nutrition, sectoral analysis, etc.

It is clear that the international research centers can do much under (i); and TAC has recommended accordingly. This first category leads into (ii) – *public policy* social and economic issues. While external assistance and investment support can be given in these areas, the identification of problems and plans for their solution is very much a problem for research, planning, and governments in the nations affected. They can be helped, but no more, by training and seminars conducted by the international centers.

Where issues affect more than one country, there is scope for more international action. This will become increasingly apparent in fertilizer supplies, commodity trade, pricing problems, and investment aid for development. In some of these matters, e.g., providing an early warning system for cereal production forecasts or for major issues of world food policy, there is undoubtedly room for concentrated international effort – governmental and nongovernmental – but these are beyond my terms of reference.

The real need, therefore, is strengthened socioeconomic work associated with the development of new technologies at research centers: international and national (including universities); national work on public policy implications of new technologies; and international effort especially on economic and environmental efforts beyond the scope of national governments alone.

Basic and Applied Research: Flexibility in Research Organization

The TAC report does touch on this question. My comment must be extremely brief and avoids the problems of theoretical delineation of the two terms. Indeed I shall make only one point: it may not be wise or necessary to tackle

"basic" problems through new institutions. Thus *triticale* is the product of basic work in Canada and elsewhere; *soybean* problems are probably better handled in such places as the University of Illinois, and some of the worrying, relatively low-yield characteristics of legumes which may have physiological and morphological explanations could be dealt with by contracts to university centers for research. TAC has started to consider this last possibility. The contractual approach is an illustration also of needed flexibility in our approach to international research. Not everything calls for an IRRI or a CIMMYT in organization terms.

Strengthening National Institutions

TAC could not possibly handle requests for strengthening national research systems, nor is the CGIAR established for this purpose. Nevertheless, TAC is clear that unless national research capacities are strengthened to an extent that enables them to take advantage of the results of international research the dividend from international research will be limited. Moreover, I do not hesitate to stress again the importance to the international centers of feedback from adaptive research within national boundaries. Sometimes this is effected by outreach programs; but Indian and even Indonesian research capacities are not typical of the many very poor countries in Africa and Asia. Accordingly TAC has strongly urged more financial and organizational support from FAO, UNDP, the World Bank, and bilateral donors for national research efforts.

Financial Constraints

As I have pointed out above, the total of core, capital, and outreach programs has risen from $12 to 14 million in 1972 to an estimated $45 million in 1975. At constant prices this could – given continued support by the group – reach $57 million in the late seventies and perhaps $64 million in the early eighties. These two figures could be $65 million and $87 million if inflation continues at recent rates. Of course, these figures would quickly increase if the group were to invite TAC to cross the borderline between regional and national research.

We have here a dilemma of concern both to TAC and to the Consultative Group. On the one hand, TAC cannot assume unlimited support; on the other, once the group offers support it must also assume reasonable continuity in that support. The group has given TAC very strong backing thus far. For its part, I believe TAC has, in its priorities, acted with care and financial responsibility. It knows very well that research programs must be reviewed from time to time and unnecessary or unpromising work deleted. It is about to establish working relations with the centers to this end. On the other hand, it

will continue to press for support for new work which it considers to be a vital contribution to the solution of the world's Malthusian situation.

I think I should finish on a note of confidence. The CGIAR/TAC system is a unique venture in international collaboration. It has succeeded beyond anyone's real expectations in 1971. We confidently await an increasing and usable output from the rising research investment. Much now depends on international and national economic and social policies to apply the actual and anticipated research results. This topic, which embraces the whole meaning of, and prospect for, development in the poorest areas of the world is beyond my brief in this chapter. However, I conclude simply by saying I do not belong to the band of hopeless pessimists. The CGIAR/TAC experiment has buoyed my hopes and expectations that good sense will yet prevail.

APPENDIXES

Appendix 11-1. Membership of the Consultative Group on International Agricultural Research

Membership as of November 1, 1974 comprised the following: Australia, Belgium, Canada, Denmark, France, Germany, Japan, Netherlands, Nigeria, Norway, Sweden, Switzerland, United Kingdom, United States, United Nations Environment Program, three regional development banks (African, Asian, and Inter-American Development Banks), the Commission of the European Communities, three private foundations (Ford, Rockefeller, and Kellogg foundations), and the International Development Research Centre, an independent Canadian organization.

The five major developing regions of the world participate in the Consultative Group through representatives designated for a two-year term by the membership of FAO. Each region has designated two countries which alternate as members at their discretion. Representing Latin America are Argentina and Brazil; representing Africa: Morocco and Nigeria; representing Asia and the Far East: Malaysia and Thailand; representing the Middle East: Egypt and Pakistan; representing southern and eastern Europe: Israel and Rumania.

The World Bank serves as chairman of the Consultative Group, FAO and UNDP as cosponsors.

Appendix 11-2. Objectives of the Consultative Group on International Agricultural Research

The main objectives of the Consultative Group (assisted as necessary by its Technical Advisory Committee, or TAC) are as follows:

(i) On the basis of a review of existing national, regional and international research activities, to examine the needs of developing countries for special effort in agricultural research at the international and regional levels in critical subject sectors unlikely otherwise to be adequately covered by existing research facilities, and to consider how these needs could be met.[4]

(ii) To attempt to ensure maximum complementarity of international and regional efforts with national efforts in financing and undertaking agricultural research in the future and to encourage full exchange of information among national, regional and international agricultural research centers.

(iii) To review the financial and other requirements of those international and regional research activities which the Group considers of high priority, and to consider the provision of finance for those activities, taking into account the need to ensure continuity of research over a substantial period.[5]

(iv) To undertake a continuing review of priorities and research networks related to the needs of developing countries, to enable the Group to adjust its support policies to changing needs, and to achieve economy of effort.

(v) To suggest feasibility studies of specific proposals to reach mutual agreement on how these studies should be undertaken and financed, and to exchange information on the results.

In all of the deliberations of the Consultative Group and the Technical Advisory Committee, account will be taken not only of technical but also of ecological, economic, and social factors.

Appendix 11-3. Original Members of the Technical Advisory Committee on International Agricultural Research[a]

1. *Sir John Crawford* (economist), Australian National University, Canberra. Chairman.	Australia
2. *Ing. Manuel Elgueta* (agronomist), Ex-director, Chilean Agricultural Research Institute; now working with IICA as director of proposed Turrialba Research Corporation	Chile
3. *Professor Dr. Hassan Ali El-Tobgy* (geneticist), Undersecretary of Agriculture and chairman of the Research Committee	UAR

[a] *Professor D. Bommer*, Head, Institute for Plant Cultivation and Seed Research, Agricultural Research Centre, was added as the thirteenth member in June 1972. — Fed. Republic of Germany

4. *Professor H. Fukuda* (irrigation specialist), Vice president, International Commission for Irrigation and Drainage, Tokyo University	Japan[b]
5. *Dr. G. Harrar* (plant pathologist), President , Rockefeller Foundation	USA[c]
6. *Dr. W. D. Hopper* (economist), President, International Development Research Centre	Canada
7. *Dr. Luis Marcano* (agronomist), President, Shell Foundation	Venezuela
8. *Dr. T. Muriithi* (animal health), Director, Veterinary Services	Kenya
9. *Dr. J. Pagot* (animal production), Directeur general, Institut d'Élevage et de Médecine Vétérinaire des Pays Tropicaux	France[d]
10. *Dr. H. C. Pereira* (physicist), Director, East Malling Research Station, Kent (Previously director, Central African Research Organization)	UK
11. *Dr. L. Sauger* (agronomist), Directeur, Centre de Recherche Agronomique du Bambey	Senegal
12. *Dr. M. S. Swaminathan* (geneticist), Director, Indian Agricultural Research Institute, New Delhi	India

Appendix 11-4. Terms of Reference of the Technical Advisory Committee

TAC will, acting either upon reference from the Consultative Group or on its own initiative

(i) advise the Consultative Group on the main gaps and priorities in agricultural research related to the problems of the developing countries, in both the technical and socio-economic fields, based on a continuing review of existing national, regional, and international research activities;

(ii) recommend to the Consultative Group feasibility studies designed to explore in depth how best to organize and conduct agricultural research on priority problems, particularly those calling for international or regional effort;

[b] Since succeeded by *Dr. N. Yamada*, Director, Tropical Agricultural Research Center, Ministry of Agriculture and Forestry — Japan

[c] Since succeeded by *Dr. V. W. Ruttan*, Agricultural Development Council, New York — USA

[d] Since succeeded by *Dr. Guy Ch. Camus*, Directeur general, Office de la Recherche Scientifique et Technique Outre-Mer — France

(iii) examine the results of these or other feasibility studies and present its views and recommendations for action for the guidance of the Consultative Group;

(iv) advise the Consultative Group on the effectiveness of specific existing international research programs; and

(v) in other ways encourage the creation of an international network of research institutions and the effective interchange of information among them.

These terms of reference may be amended from time to time by the Consultative Group.

NOTES

1. The present paper is an edited and updated version of my Hannaford Lecture entitled "International Agricultural Research: An Encouraging Venture in International Collaboration," given at Adelaide University, Adelaide, Australia, on November 26, 1973.

2. For background on the early development of the international system, see E. C. Stakman, Richard Bradfield, and Paul C. Mangelsdorf, *Campaigns against Hunger* (Cambridge, Mass.: Belknap Press of Harvard University Press, 1967); also, Sterling Wortman, "Extending the Green Revolution," *World Development*, 1:12 (December 1975), 45-51.

3. An example is plant nutrition which is currently under consideration by TAC.

4. Research is used in this document in a broad sense to include not only the development and testing of improved production technology, but also training and other activities designed to facilitate and speed effective and widespread use of improved technology.

5. Final decisions on funding remain a responsibility of each member in connection with specific proposals.

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The International Rice Research Institute (IRRI) Outreach Program

Nyle C. Brady

International agricultural research centers are an innovative approach to the use of science in solving the world's food problem. They are sharply focused scientific establishments which, though located in developing countries, are as well equipped and manned as any in the developed world.

There are two primary criteria for the success of international agricultural research centers. First, they must be *centers of excellence*, applying the world's best scientific talent to the practical problems they were established to solve. They must develop superior varieties, strains, cultural practices, and farming systems on which improved technology for the developing world can be based.

Second, the international centers must serve as *stimulating and collaborating forces to improve the quality and output of national research programs.* They must do more than merely make their products available for use by other countries. They must work collaboratively to improve the scientific expertise, operational efficiency, and output of the national research programs.

IRRI's Traditional International Involvement

From its inception, IRRI has fulfilled this dual role – as an emerging center of excellence and as a collaborator with rice-production countries.[1] Although it was necessary in the early days of IRRI's history to emphasize the develop-

ment of excellence, the international role was not neglected nor could it have been.

The Collection of Germ Plasm

The original seeds collected for IRRI's germ plasm bank came from existing national stocks or from samples collected by collaborators in cooperating countries. The practice of splitting each sample collected, retaining one portion in the country of its origin, and sending the other to IRRI set the stage for this mutually beneficial program. More than 33,000 samples have been collected from cooperating countries.[2]

As the seed bank has grown, the return flow of samples to national programs has expanded. In 1973, nearly 8,000 samples were sent to scientists working in national programs. Similarly, seeds of lines from IRRI's breeding programs are furnished upon request to country scientists. About 8,000 samples of these lines were sent in 1973.

Publications

In 1963, IRRI published a bibliography of the world's literature on rice. This publication, which is supplemented annually, is very helpful to researchers in developing countries who cannot easily translate Japanese, the language in which much of the rice literature is published. Photocopies are made available upon request, a significant service to national research agencies.

IRRI scientists have written a number of books and special publications on rice and its enemies. The institute also publishes the proceedings of important conferences and symposia and makes them available to scientists in cooperating countries.

The quarterly *IRRI Reporter* provides brief summaries not only of research findings at IRRI but of research done in cooperation with scientists in other countries. The IRRI annual report contains more detailed information on research accomplishments.

Conferences, Symposia, and Workshops

Conferences, symposia, and workshops which provide opportunities for communication among rice workers have been held regularly since the institute was established. The annual international rice conference, initiated in 1969, has traditionally provided opportunities for scientists and research administrators to review research results from all important rice-growing areas. This annual conference is now being used also for making cooperative plans for future programs.

A series of special symposia has permitted rice scientists to explore in

depth subjects of broad interest to them. Scientists from both the developing and the more developed world are invited. A symposium was recently held on "Climate and Rice," the eighth major symposium held since the institute was founded.

Training

IRRI's training program seeks to upgrade the expertise of rice scientists and educators in cooperating countries. Selected in consultation with officials in their home countries, the trainees participate in one of two types of training. Those with extension and applied research orientation are involved in one of two six-month production research training courses. In the first course, they gain practical experience in all phases of rice production; in the second, they study rice-cropping systems. After completing these courses, participants are prepared to give similar training to extension workers in their own countries. Such training imparts needed knowledge and skills, but perhaps more importantly it is a source of pride to those who have worked together as a team using science to help farmers produce more food.

Those trainees who are research-oriented can participate in short on-the-job research training programs or, if their needs dictate, they can take course work at the University of the Philippines at Los Baños to fulfill the requirement for the M.S. or the Ph.D. degree. Their thesis research is done at IRRI, giving them an opportunity to gear this research to the practical problems they will face when they return home.

In some cases it is desirable for the trainee to take some graduate courses at a university in the United States or in Europe. However, the scholar must return to IRRI to do his research work on a problem of some relevance to his own country. Whether the IRRI scholars and fellows obtain their academic training at Los Baños or in the Western Hemisphere, they have the advantage of orienting their research to the solution of practical problems. Furthermore, they do their research in a cultural environment more similar to their own than are those of the United States or Europe.

Postdoctoral research is provided for a select group of young scientists from rice-growing countries. Some are scientists working in national programs. Others have recently completed their Ph.D.'s and need to focus on rice-production problems before returning home.

Since IRRI began its training program in 1962, about eight hundred man-years of training have been given to scientists and educators from forty-five countries. Most of the students have come from South and Southeast Asia although a number have come from Africa and Latin America and a few from Europe and North America. Currently, IRRI provides about ninety man-years

of training each year, twenty-five of which are for nondegree scholars and fellows, fifty-five for those registered for M.S. and Ph.D. degree training, and ten for postdoctoral fellows.

Four Cooperative Approaches

IRRI's cooperative programs with national research organizations have four primary objectives: to do location-specific research which cannot be done effectively at IRRI headquarters in the Philippines (this is called collaborative research); to develop international research networks on problems of common interest (international testing); to strengthen national research capabilities (outreach services); and to strengthen the countries' capacities to utilize research findings in rice production programs. Any given cooperative project may have more than one of these objectives. In some cases, all may be involved.

Collaborative Research

IRRI scientists often find that major problems cannot be attacked conveniently at our headquarters in Los Baños. For example, some serious insect and disease pests are not found at that location, and yet it is essential that IRRI's varieties and breeding lines be thoroughly tested for resistance to the pests in question. Examples are research on the gall midge insect in India, on the tungro virus disease in Indonesia, and on a suspected biotype of the brown plant hopper in India.

The tolerance of different rices to toxic soil conditions (such as those brought about by excessive salt, acidity, alkalinity, or iron) can also best be ascertained if tests are run where the problem exists. Arrangements are being made with scientists in India and Sri Lanka to carry out field screening trials to identify varieties with greater tolerances to toxic conditions.

In some cases, collaborative research can be done overseas with little direct input from IRRI other than in the planning stages. The research is sufficiently important to the cooperating countries to justify additional national financial and personnel inputs without outside assistance. Testing IRRI lines in parts of Indonesia infected by tungro virus and in areas in India with brown hopper pressures are examples. In other cases, IRRI scientists are involved not only to help with the overseas research but to carry out supplementary and complementary experiments at IRRI headquarters. Research on flood-tolerant lines and varieties in Thailand and at IRRI headquarters is an example.

Collaborative research may also be undertaken with more than one other country. An example is research being planned on deep-water rice, a type of culture found in approximately 10 percent of the rice area of Asia. The area

of deep-water rice in the Philippines is insignificant, but large areas are found in Bangladesh, Thailand, India, and Indonesia. We are developing a cooperative research program with the Ministry of Agriculture in Thailand to work on deep-water rice. Two IRRI scientists located in Thailand will collaborate with their Thai counterparts in expanding and strengthening an ongoing deep-water research program there. They will also collaborate with scientists in other deep-water rice countries.

There are many research areas of mutual interest to IRRI scientists and their associates in India. We have signed a memorandum of agreement with the Indian Council of Agricultural Research which provides for collaborative research planning and implementation as well as for the exchange of scientific personnel. Each year a work plan is developed. This plan clearly identifies the areas of mutual interest, the division of responsibility in carrying out the needed research, and the areas in which personnel will be exchanged. This procedure has many advantages and is being pursued in a modified form in the Philippines and in Thailand.

Although the primary objective of collaborative research is to find answers to specific problems, a secondary objective is the strengthening of national research capabilities. In implementing the research, both IRRI scientists and their counterparts improve their capabilities. New techniques are developed and utilized. Interdisciplinary approaches are fostered. This procedure provides training in a framework that is satisfying to scientists from IRRI and the developing countries alike.

International Networks

The second phase of IRRI's outreach program is the development of international research networks. These networks permit scientists from different countries to plan and implement research projects in several countries at once using common objectives and procedures. At present, three networks are in existence or are being set up: the international testing program for Genetic Evaluation and Utilization (GEU); the International Rice Agro-Economic Network (IRAEN); and the International Cropping System Network (ICSN). Other informal networks exist for research on herbicides and fertilizers.

IRRI's initial objective is to serve as a catalyst for these networks. Once a general area of mutual interest is identified, scientists from cooperating countries are brought together to set up the general framework for the network and to determine the specific experiments, surveys, or studies to be done.

In some cases, IRRI or one or more of the cooperating countries may have already run some pilot experiments in the research area which serve as a guide. For other projects, a loose cooperative framework may already exist which needs only formalization for the specific experiments in question.

National research personnel must be fully involved in the planning and the implementation of the network. In no case can the impression be given that the network is merely an extension of IRRI's program. To be successful, the network research must be planned and carried out by the country scientists.

In each of the three projects currently under way we have assigned an IRRI scientist to serve as network coordinator. In the genetic (GEU) trials, for example, the coordinator is responsible for collecting seeds of lines and varieties to be tested and for disseminating them among the cooperators. He facilitates communications among cooperators and coordinates the exchange of biological materials, the collection and collation of data, and the planning of workshops or conferences. The coordinator visits the countries involved and reviews ongoing experiments and program plans with cooperators.

If funds permit, scientists from one country are encouraged to visit experiments in other countries so they can see more clearly how the international network can be useful to them. These visits also have some training value, because new techniques are demonstrated and innovations evaluated.

The international testing network of the Genetic Evaluation and Utilization (GEU) program has been in progress since the early sixties. In cooperation with national research centers, nurseries have been set up to screen rice lines and varieties for insect and disease resistance. For example, more than 300 international blast nurseries have been conducted in twenty-five countries since 1963. Similar tests for bacterial leaf blight were initiated in 1972 and for sheath blight in 1973. International yield trials were initiated in 1973, and observational nurseries are being established for the general evaluation of several hundred of the best selections from both national and international sources.

Recently, the international testing program has been expanded to include international nurseries for adverse soil and weather conditions as well as for the major insects and diseases. Observational nurseries and yield nurseries are also included. The tests involve upland rice as well as paddy rice nurseries.

The Agro-Economic Network (IRAEN) is based upon the success of a preliminary cooperative study among economists and agronomists from several countries who were concerned with rice yields in relation to different types of farming. The IRAEN has been concerned initially with international study of constraints on yields in farmers' fields. It is innovative in that its success depends upon the close collaboration of economists and agronomists who will attempt to measure the relative importance of different factors constraining rice yields under different environmental conditions in South and Southeast Asia.

Planning and implementation of the Cropping System Network are accomplished using procedures similar to those used by the GEU and IRAEN. Po-

tential research locations have been chosen on the basis of broad agroclimatic regions. A network coordinator has visited most of the countries of Southeast Asia. In consultation with local scientists, potential sites for cropping systems trials have been identified in Indonesia and the Philippines, and discussions are under way with scientists from other countries.

IRRI scientists have great expectations for the international networks system. It gives country scientists experience in conducting research. It illustrates the international nature of science. It provides IRRI scientists with a better understanding of the problems faced by farmers and by researchers in the cooperating countries.

Strengthening the Capacity of Country Research Programs (Outreach Services)

Most of IRRI's activities – collaborative research, international networks training, distribution of seed samples – are aimed at strengthening national research capabilities. They are complemented by formal country-assistance projects.

The prime objective of these projects is to enable local scientists to improve their skills and the national agency to develop a workable research system. In these projects, IRRI scientists are located in the cooperating country. These scientists function as members of the local staff, not merely as IRRI overseas employees. Their operational support comes largely from local sources.

The three major functions of IRRI scientists working in cooperative country programs are the following: to provide temporary research expertise which permits national research programs to begin while local staff are receiving formal training outside the country; to offer on-the-job training for their counterparts in national programs; and to assist in the development of a viable system of rice research and of a managerial framework within which that research can be implemented.

Since 1960, IRRI has undertaken twelve country projects in Pakistan, Bangladesh, India, Sri Lanka, Indonesia, Vietnam, Egypt, and the Philippines. Although not all of these projects have been successful, together they have played a major role in the general steady improvement of the research and institutional capabilities of the countries involved.

Strengthening the National Capacity to Utilize Research Findings

For several years, IRRI has been involved in a pilot project aimed at putting research results into production more rapidly. This project involves a series of applied research trials planned and implemented cooperatively with

the national research and extension organizations. These in turn become the basis for a pilot action program operated by the cooperating country and, if this is successful, a nationwide production effort based on the applied research findings.

This procedure has been tried in the Philippines with some success. The applied research trials were concerned first with a "package" technology approach and then with a direct-seeding two-crop management system which will permit two crops to be grown in rainfed areas where only one grew in the past using the conventional cropping systems. The trials were run on farmers' fields with the aid of IRRI-trained technician-employees of the extension service. The Philippine government utilized the technology demonstrated in the fields to set up the "Masagana-99" national rice production program in the Philippines. This program appears to have been reasonably successful in spite of shortages and high costs of inputs as well as typhoon and flood damage during the past two years.

The Philippine experience is still considered a pilot operation. Depending on a final assessment of this preliminary work, similar programs in other countries may be initiated, starting in 1976.

Operational Constraints

IRRI scientists and administrators have given considerable thought to steps which might improve IRRI's international programs, particularly the cooperating-country projects.

We have identified at least three major problem areas which tend to limit our success. These are limitations on IRRI's ability to provide the needed assistance; limitations on the ability of the national agency to use the assistance effectively; and limitations stemming from the fragmentation and lack of continuity of donor inputs into the national research programs.

IRRI faces several problems in working effectively to improve national research capabilities. First, there is the difficulty arising from the dual role played by IRRI: an aggressive "doer" of research on the one hand and a less aggressive "tutor" for research on the other. Some difficulty is experienced in taking steps to strengthen the training and the organizational and managerial capabilities of country programs without giving the impression that the external organization is dominating the local scene. Fortunately, in most cases the selection of IRRI staff for the overseas assignments has been such that the "dual role" has been minimized. Working relationships at the country level are good.

A second limitation on IRRI's ability to be more helpful relates to the lack of research coordination and management expertise in national agencies. Frequently, the greatest need does not stem from the inadequacy of the local

scientist but rather from the inadequacy of the research system of which he is a part. This need for managerial assistance is attributable to both the constraints on the national researchers and the complexities resulting from the fragmentation of donor assistance.

The limitations experienced by the national research agencies are well known. In some cases government restrictions and inflexibilities set up almost insurmountable roadblocks to the development of viable agricultural research programs regardless of the external support provided. In others, low staff salaries and inadequate operational support funds give little opportunity for local staff to innovate and reorient programs. In still others, the rate of change needed in the organizational and operational frameworks is more rapid than any but the most innovative administrators and political decision-makers will permit.

The problems facing national research agencies are attributable as much to organizational and managerial weaknesses as to the inadequate training of scientific personnel and the low quality of the research being conducted. At the same time, research achievement can solve the problem in some cases. It has been said, for example, that IR-8 and other high-yielding varieties brought about more change in the organizational and managerial frameworks of national rice research programs than all the research coordinators, administrators, and other nonresearch advisers combined. Although this may be an overstatement, IRRI is working on the assumption that research accomplishments can influence decision-makers. We will do all we can to help the country researchers achieve these accomplishments. At the same time, other efforts will be continued to help improve the rice research systems of our cooperators.

The fragmentation and lack of coordination of donor assistance to national rice research programs are serious obstacles in some cases. Each donor provides assistance to alleviate the constraints on research as perceived from his institutional point of view. In some instances this viewpoint has a political flavor which relates as much to the objectives of the donor as to those of the cooperating country. While this situation appears to be inevitable where donor assistance is given by outside national aid agencies, it does not make research coordination easy to achieve.

Fortunately, donor agencies do at times coordinate their activities well, making IRRI's job of assistance easier. Plans are made jointly by representatives of the national agency, the donors, and IRRI. Support from each agency is agreed upon, and the program is implemented.

A second donor-related constraint is the lack of continuity of funding for the cooperating country projects. These projects are often of two to three years' duration only. Although such time limits accord with justifiable donor policies, they constitute a serious constraint on the employment of competent

personnel. Also, the seemingly unavoidable delays in approval of project extensions is bad for staff morale. Furthermore, with the fate of IRRI international staff at stake, it is very difficult to bring about needed changes in projects as they are renewed. Moral commitments to existing staff limit our bargaining power to obtain needed changes in contract provisions.

What of the Future?

We are optimistic about future cooperative relationships between international research centers and country agencies. These relationships are helping to move research results from the experimenter's plots to the farmer's field. Furthermore, they are identifying which of the experimenter's results will be most useful to the farmer.

Our optimism is based on the assumption that certain clear guidelines will be followed in center-country program relationships. These guidelines include the following.

1. There must be a clear delineation of the responsibilities of each center in respect to both the coverage of science subject matter and the methodology to be used. This delineation must be made by the administration and governing boards of the centers and must be clearly understood by donors and national organizations alike. Centers should not be called upon to perform activities for which they do not have a comparative advantage. For example, they should not be used as substitutes for the type of general-assistance programs formerly carried out by donors.

2. Each special project involving a center and a national program should be directly related to the long-term goals of both the center and the country program. To assure this, a joint analysis by both organizations of the country's long-term agricultural research and training goals is desirable.

3. The quality of center personnel in country projects should, to the extent feasible, be of the same caliber as that found in the center's core program. The scientist's training must fit his responsibilities in the country, but scientists assigned to country programs should not be second rate. If we are to have competent scientists in country programs, longer term commitments must be made to these scientists, and they must be given perquisites comparable to those enjoyed by scientists located at center headquarters.

4. A fiscal and personnel management system must be developed at each center to permit the full exploitation of opportunities for collaboration and cooperation with country programs. This means that core program donors should realize that some scientist and administrator time will be involved in assisting country programs. This time should be recognized as being as legiti-

mate in carrying out the goals of the center as is any other phase of the core program.

To accommodate expanding country-center programs additional scientific and managerial talent must be recruited. This additional help is needed to prevent the erosion of core programs, which in many instances are thinly staffed.

A sounder financial base must be provided for centers to carry out their obligations and opportunities with cooperating countries. Funds are also needed to support exploratory studies and the staff time required for the development of projects before they are funded by an outside donor.

5. The role of the international centers in providing assistance to national programs must be subject to continuing scrutiny, not only by the center governing bodies but by the consultative group as well. Projects dealing with subjects central to the missions of the centers should be developed and initiated by or in cooperation with the centers.

The challenge to both the centers and the national programs is to carry out their symbiotic relationships without endangering their common primary function – to bring science to bear effectively on the solution of the world's food problems. The challenge for donors is to provide long-term funding for quality center-country programs which have as one of their prime objectives the enhancement of research capabilities within countries.

NOTES

1. A. Colin McClung, "IRRI's Role in Institutional Cooperation in Asia," *Rice, Science and Man* (Los Baños: International Rice Research Institute, 1972), pp. 19-40.

2. See T. T. Chang et al., "The Genetic Conservation Program of IRRI," report prepared by a committee of IRRI scientists (Los Baños: International Rice Research Institute, December 1974).

13

The International Maize and Wheat Improvement Center (CIMMYT) Outreach Program

Haldore Hanson

Background on CIMMYT

CIMMYT's mandate is to improve the quantity and quality of maize and wheat wherever they can be grown efficiently, but especially in developing countries.

The maize program includes cool-tolerant sorghum, a possible substitute crop for maize at high elevations, and wide crosses attempted between maize and other species of plants (for example, maize x tripsacum, maize x sorghum).

The wheat program includes bread wheat, durum wheat, barley, triticale (a cross of wheat x rye), and other wide crosses attempted between small grains (for example wheat x barley, wheat x oats).

The reference in the mandate to the "quality" of crops applies particularly to the protein content of cereals.

Wheat or maize is the basic foodstuff of a majority of the developing countries. These two crops are eaten by more than one billion people. Together with rice, which stands first in production in the developing countries, they constitute over 80 percent of the cereals eaten by poorer nations.

If we arbitrarily decide that 100,000 hectares planted to a given cereal crop makes that crop an important national food, then there are seventy maize-growing countries and sixty wheat-growing countries in the world.

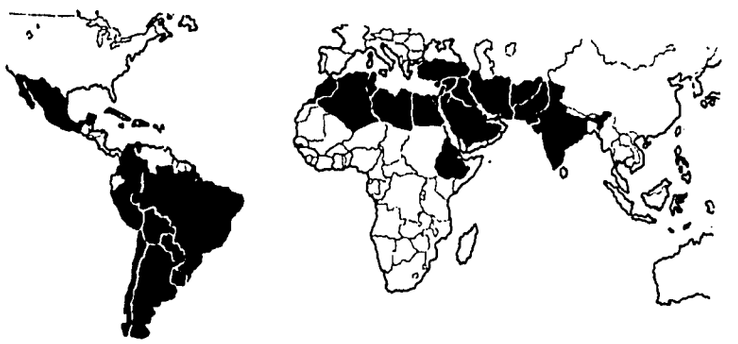

Figure 13-1. Wheat: Developing countries in which wheat is an important crop (over 100,000 hectares of production per country or over 25 percent of national calories derived from the crop).

Fifty-three of the maize growers and thirty of the wheat growers are developing countries.

If we add to the list of developing countries those which produce less than 100,000 hectares of maize or wheat but derive more than 25 percent of their total calories from one of these crops, we find a total of more than sixty national maize programs and forty national wheat programs which deserve attention from CIMMYT (see Figures 13-1 and 13-2).

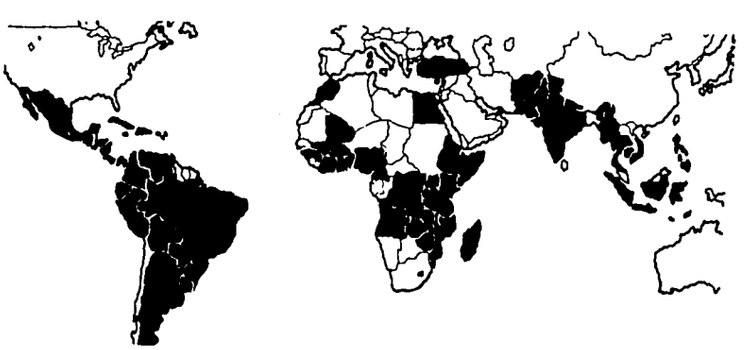

Figure 13-2. Maize: Developing countries in which maize is an important crop (over 100,000 hectares of production per country or over 25 percent of national calories derived from the crop).

When we compare this potential workload with the size of CIMMYT's headquarters staff, which includes thirteen scientists for wheat and thirteen

for maize, it is clear that only a remarkably efficient use of resources will permit so small a staff to have an impact on production in so many countries.

One fact that influences CIMMYT planning is revealed in the statistics cited above: although the wheat crop in developing countries is somewhat larger than the maize crop – 79 million tons compared with 62 million tons – more countries are staple maize-eaters than wheat-eaters. Consequently, the maize staff at CIMMYT must deal with more governments than must the wheat staff. Later in this chapter, when we discuss proposals for regional programs involving groups of producing nations, it will be seen that CIMMYT recommends six maize-producing regions compared with four wheat-producing regions.

Services for National Programs

The requests for assistance which CIMMYT receives suggest that the primary needs of many countries are (1) better germ plasm (seed) and improved production technology; (2) the training of institution/agency staff who will test and introduce better technological methods into their countries; and (3) advice on all aspects of food production for such decision-makers as the president, the staffs of various agricultural service agencies, and the farmer himself. An international center must be prepared to participate in most of these fields if its effectiveness is to be measured by rising national crop yields.

There are many aspects of national crop improvement in which the international center can offer only marginal expertise. Salient among these are investments in fertilizer factories and social reforms affecting land tenure and political-economic decisions, such as whether to grow more food at home or to import more food at concessional prices. (The latter issue held back wheat production in the Andean region for more than two decades.)

A successful breakthrough in crop technology, such as the packaging of Mexican dwarf wheat and its production practices, has conferred a creditability upon CIMMYT which carries far beyond the agricultural sciences and causes governments to ask advice on a wide range of production factors. In this situation CIMMYT must exercise caution and refer some requests for advice to more appropriate specialists.

CIMMYT's Predecessor

CIMMYT became a legal entity with an international mandate in 1966, but during the preceding two decades, starting in 1943, CIMMYT's predecessor agency was a cooperative research and production program for basic foodstuffs in Mexico, cosponsored by the Mexican government and the

Rockefeller Foundation. During these two decades, CIMMYT's research, training, and outreach activities took shape.

Norman Borlaug, director of the wheat program since 1944, conducted his wheat breeding in Mexico in two cycles a year, one winter crop under irrigation in Sonora State at latitude 29° N (sea level) and one summer crop in rainfed conditions on the Mexican high plateau near Toluca at 19° N (elevation 8,700 feet). The result of this biannual movement over many cycles was a wheat type which was adaptable to the day length, temperature range, moisture conditions, and tolerance for diseases of the two climates. This adaptation became a major factor in the success of Mexican wheats when they were moved half way around the world to the Punjab of India-Pakistan in the 1960s and were found to be well adapted there.

Another development of this early period was the Mexican training program. More than 400 Mexicans were given in-service training for research on wheat, maize, and beans. More than 200 did work toward the M.S. degree, and more than 80 received their doctorates. This group of agricultural scientists trained in the 1940s, 1950s, and 1960s now provides leadership for most of the agricultural agencies in Mexico, from the minister of agriculture on down. The lessons learned from this training program still offer insights for the needs of many other countries.

Finally, the Mexican program in the 1950s and 1960s served as a stepping stone for Rockefeller Foundation scientists who first gained experience in Mexico and then helped other Latin American countries – Colombia, Ecuador, and Chile – establish similar crop improvement programs. These foundation men carried with them the experimental maize and wheat from the Mexican program, and soon there were inter-American nursery trials, which set the pattern for the later international workshops among this group of nations.

Thus many of the activities that CIMMYT now calls "outreach" were tested and improved in those early years before CIMMYT became an international center.

Services from CIMMYT Headquarters

Strengthening national production programs is the basic objective of CIMMYT and the other international centers. Our headquarters program is organized to achieve this end. CIMMYT distributes seed, production technology, and training services to national production programs in a variety of ways.

Consulting with Governments

CIMMYT's senior staff spend between 15 and 20 percent of their working time traveling outside Mexico, consulting with governments of wheat- and

Table 13-1. Locations of CIMMYT Nursery Trials in 1974

Region	Countries Conducting Trials[a]		Trials per Region	
	Wheat	Maize	Wheat	Maize
Latin America	14	12	297	127
Asia and Pacific	12	7	196	60
North Africa and Near East	17	4	273	13
Africa south of the Sahara	17	13	122	36
Europe, Canada, U.S.	26	3	316	1
Total	86	39	1,204	237

[a] A total of ninety-three different countries.

maize-growing countries, or exchanging information with research institutions. This international travel required 1,823 man-days (about five man-years) in 1972 and 2,500 man-days (about seven man-years) in 1974.

Consultation by CIMMYT staff has been increasing steadily over the past five years and has reached an approximate limit for the present size of the headquarters staff. Future increases in consulting will be accomplished by stationing CIMMYT staff members in the various producing regions, as will be discussed later.

International Nursery Trials

International nursery trials distributed from CIMMYT were grown in ninety-three countries in 1974. These trials represent CIMMYT's principal method for distributing improved germ plasm and outstanding breeding materials to developing countries.

An "international trial" consists of identical packages of experimental seed sent to a network of collaborating scientists throughout the world. These scientists are asked to grow the seed under a standard set of procedures, using their best local varieties as checks, and to return the data to CIMMYT. CIMMYT then analyzes and publishes the results.

CIMMYT began its international nurseries for wheat in 1960 and for maize in 1971. In 1974, wheat trials were grown at 1,204 sites in eighty-six countries and maize trials were grown at 237 sites in thirty-nine countries. The objectives are (1) to test new lines of wheat and maize under widely differing conditions of day length, temperatures, moisture, diseases, and insects; (2) to obtain yield data which can guide the breeding work of the entire network, including CIMMYT; (3) to train a network of cooperating scientists; and (4) to obtain from these scientists, in exchange, their best experimental germ plasm for inclusion in future trials and in CIMMYT's crossing program.

Scientists estimate it would take any one collaborator fifty years of repeat-

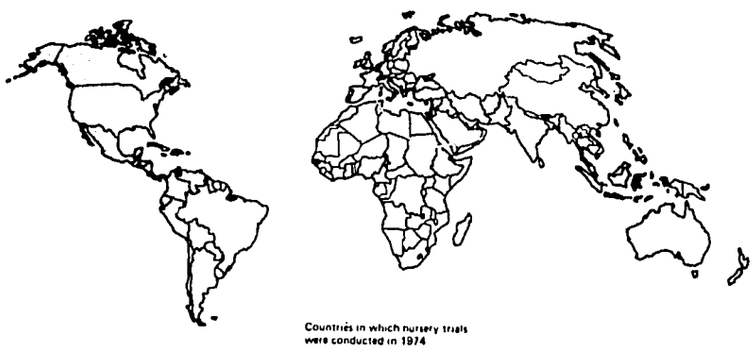

Figure 13-3. Location of CIMMYT nursery trials, by region, 1974.

ed trials in his own stations to obtain data as comprehensive as that from one year's trial on a worldwide basis.

Locations of the CIMMYT nursery trials of 1974 are shown in Table 13-1 and Figure 13-3.

The Germ Plasm Bank

CIMMYT maintains a germ plasm bank for maize seed – the largest maize collection in the world – from which breeders may request samples of seed carrying particular genetic characteristics. For example, a breeder in Argentina seeking genetic resistance to a pest called fall army worm can request seed samples for all bank entries which CIMMYT believes will provide this characteristic. The maize bank contains about 11,000 entries for the maize species and its close relatives. In 1973 the bank made forty-four seed shipments to breeders in nineteen countries.

CIMMYT's wheat staff does not maintain a world collection for bread wheat, durum wheat, and barley, but only working collections. Therefore, CIMMYT sometimes refers wheat requests to the USDA, which maintains a world collection of small grain germ plasm.

In-Service Training in Mexico

From 1966, when CIMMYT began, through 1974, 500 young scientists from developing countries have come to CIMMYT for practical experience in research and production. Courses last six to nine months and include one complete cycle of crop research plus some lectures in basic agricultural sciences. No degree is awarded. CIMMYT now receives about 100 fellows a year – of whom a small percentage are women – for this type of training.

The fellows who come from research services participate at CIMMYT in

data analysis and in all research activities from planting to harvest. Those employed as production agronomists receive some research experience at CIMMYT but also help to lay out field trials on private farmers' land. This is an activity which the agronomist will be expected to perform upon returning home.

All CIMMYT training courses stress "learning by doing," "dirty hands," and the discipline of working under heat, humidity, heavy rains, and long hours. We do not know how to teach motivation, but we find that many training fellows leave Mexico with a new drive.

Visiting Scientists in Mexico

A program for visiting scientists and administrators brings over 100 persons each year from developing countries to CIMMYT. This activity reaches a different age group and serves a different purpose than does the in-service training program.

In developing the visiting scientist program, CIMMYT reasoned that, if it gives in-service training to a group of young scientists from a country like Tanzania, it is useful for the research director of that country to spend one or two months at CIMMYT during a harvest season observing how research decisions are made. Moreover, CIMMYT felt that such a country's vice minister or minister of agriculture could spend a profitable week at the institute.

Several benefits can be observed after these visitors return home. First, those who are practicing scientists make greater use of international germ plasm and become key members of the international network which grows the international nurseries. Second, the visitors give active support to the CIMMYT training programs, nominating the best candidates, helping to arrange study leaves, and showing interest in the work of the trainees after they return to their posts. Finally, administrators among the visitors take an active role in the food production problems of their countries.

Doctoral Fellows in Mexico

Candidates for doctoral degrees at North American or European universities come to CIMMYT for twelve to eighteen months to do their thesis research under supervision of CIMMYT scientists and then return to their universities to qualify for the degree. Under another option, postdoctoral fellows are invited by CIMMYT to serve two years as junior members of the CIMMYT staff.

Since 1966, seventeen predoctoral and twenty-five postdoctoral fellows have received grants to spend one or two years in Mexico. Of these, twenty-two have completed their work and – without exception – each is now employed in crops research work, either by his own government or by one of the

international centers. There were twenty fellows holding pre or postdoctoral grants in 1974.

Assistance with Economic Studies

CIMMYT established an economics program in 1971, and these services to developing countries are still evolving.

We believe that CIMMYT can best conduct its economics work through indigenous social scientists in national programs, helping them gather better farm and market data, which is needed by local policy officials and local biological researchers.

In 1974 CIMMYT was working with twelve countries in Asia, Africa, and Latin America on three types of problems.

1. What characteristics of farms, farmers, and agricultural policy have influenced the adoption of new technology for maize and wheat? Eight studies, covering the following crops and countries, were completed in early 1975: *Wheat* – India, Iran, Turkey, and Tunisia; *maize* – Colombia, El Salvador, Mexico (Plan Puebla), and Kenya. Most of these individual studies will result in a Ph.D. thesis by an indigenous researcher, reflecting CIMMYT's concern for augmenting national capacity to do micro-research.

2. What information is needed by policy makers to promote new technology, and how can these data be assembled? On this topic as well, CIMMYT is collaborating wit'. indigenous researchers.

3. How can economists and agronomists better work together in national programs? This research is motivated by the question: what is the minimum amount of information necessary to make useful recommendations to farmers, given that researchers have better control over the crop's environment than do farmers and assuming that farmers are risk-averting income seekers.

The economics staff also works with doctoral fellows from developing countries who do their thesis research in agricultural economics at CIMMYT. Each thesis topic is focused on a theme of interest to CIMMYT.

Beyond this the economists are collaborating with CIMMYT plant physiologists in identifying agroclimatic regions of the world, structured in terms that are significant for maize and wheat research. This information, coupled with socioeconomic data, will help define research priorities at CIMMYT geared to the needs of the producing countries.

Assistance in Laboratory Management

Two of CIMMYT's laboratories in Mexico – for protein analysis and wheat industrial quality – have assisted a number of developing countries in setting up similar laboratories.

These CIMMYT laboratories have trained more than twenty technicians

from national programs during 1972-74. They have also produced "cookbook" bulletins on laboratory procedures for use in developing countries.

With funds made available by the UNDP and others, CIMMYT has assisted in the purchase of equipment and the establishment of protein-quality laboratories in twelve countries (Algeria, Colombia, Egypt, El Salvador, India, Mexico, Nepal, Pakistan, Peru, Philippines, Thailand, and Tunisia).

As the problem of protein deficiency in national food supply becomes more acute, CIMMYT's assistance for protein laboratories is expected to rise. The demand is immediate for those countries introducing high lysine maize; these must maintain constant surveillance over the amino acid content of the experimental maize varieties.

Assistance for Research Station Management

The manager of the eight experiment stations used by CIMMYT in Mexico — Mr. John Stewart — consulted with six countries on experiment station management in 1973-74. These countries were Algeria, Nepal, Pakistan, Tanzania, Turkey, and Zaire.

Another six countries have sent experiment station managers to Mexico for training under Mr. Stewart at the CIMMYT stations: Brazil, Bolivia, Egypt, El Salvador, Ivory Coast, and Nigeria.

During a staff review of CIMMYT programs in 1974, the maize and wheat staffs said that the consulting work by Mr. Stewart, outside Mexico, had made the difference between research data which were useless and data which were highly significant. The changes were brought about by land leveling, fencing, better and more timely seedbed preparation, more accurate fertilizer placement, more timely plant protection, and better maintenance of equipment.

International Symposia

During 1971-74 CIMMYT held six international symposia in Mexico, bringing together a part of the world network of scientists on wheat or maize with a group of scientists from advanced countries, to review past research and make future plans. Most symposia last five days. About half the participants are from developing countries.

A record of proceedings for each symposium becomes a major publication for distribution to the network of scientists. In addition, the presence of so many visitors at CIMMYT leads to side meetings at which scientists from developing countries are able to negotiate for financial grants with donors, select germ plasm from CIMMYT's research fields, interview their trainees, or hold group meetings for neighboring countries of Southeast Asia, tropical Africa, and so on.

Table 13-2. CIMMYT Bilateral Assistance to National Programs in 1974 (Financed by Special Grants)

Country	Crop[b]	Number of CIMMYT Staff 1974	Donor	Starting Year	1974 Budget through CIMMYT (rounded)
Algeria-Tunisia[a]	Wheat	8	Ford and Rockefeller foundations, USAID	1968	$480,000
Argentina	Maize, wheat	0	Ford Foundation	1968	8,000
Egypt	Maize	1	Ford Foundation	1968	40,000
Lebanon	Wheat	2	Ford Foundation	1973	60,000
Nepal	Maize	1	USAID	1972	60,000
Pakistan	Maize, wheat	3	Ford Foundation	1965	155,000
Tanzania	Maize	2	Ford Foundation, USAID	1973	46,000
Turkey	Wheat	2	Rockefeller Foundation	1970	118,000
Zaire	Maize	4	Government of Zaire	1972	280,000
Total		23			$1,247,000

[a] Combined grant.
[b] Wheat assistance includes bread wheat, durum wheat, barley, and triticale.

Publications by CIMMYT

CIMMYT publishes an annual report, a scientific newsletter, and technical bulletins in three languages: English, Spanish, and French. The mailing list for English totals 4,000, that for Spanish 4,000, and that for French 1,000.

For each publication and each language there is an inner core of significant readers, made up of scientific collaborators, donors, and staff members of other international centers. This core is no larger than 1,000 people. The balance of each mailing list is made up of libraries, universities, government agencies, and requesting individuals and institutions, over half of them in countries where CIMMYT collaborates with maize and wheat programs.

The French language distribution goes largely to nineteen former French or Belgian countries in Africa.

Outreach by CIMMYT Staff Posted outside Mexico

Since 1966 CIMMYT has posted a growing number of staff in national programs to assist their national research and production activities. In 1974 there were twenty-three CIMMYT staff on residential assignment. The bilateral assistance projects are summarized in Table 13-2.

Before being posted abroad, most of this staff served as scientists in CIMMYT headquarters or held postdoctoral fellowships in Mexico.

The majority of CIMMYT's bilateral projects were initiated by donors who were seeking technical leadership for agricultural assistance which they were prepared to finance. In a few instances, CIMMYT initiated conversations directly with the host government and then solicited donor funds.

Bilateral assistance projects involve a number of activities which differ from the work of CIMMYT headquarters. Such activities are the following:

1. Research on farming systems for wheat in Algeria and Tunisia, including the introduction of medicago (forage legumes) as part of the wheat rotation and the use of biennial fallow in North Africa.
2. Selection of winter wheat in Turkey. (Mexico lacks the necessary climate.)
3. Breeding and selection for diseases and insects not prevalent in Mexico.
4. Agronomic testing of maize-legume rotation in eastern Zaire, where chemical fertilizer has always been in low supply.
5. Developing agronomic packages of practices adapted to each national program and formulating local recommendations to farmers.
6. Training local staff within national programs, especially production agronomists.

CIMMYT itself benefits from the bilateral projects. Among the hundreds of international nursery trials, those grown by CIMMYT staff in the countries listed in Table 13-2 are considered to produce more reliable data than the average; hence they serve as checks in reviewing the total returns.

CIMMYT also has its staff from bilateral projects attend each symposium at CIMMYT. The contribution of these scientists is especially useful because they are fully trained in CIMMYT methods, and they observe CIMMYT breeding materials under different environments.

CIMMYT outreach staff residing in countries where projects are under way are able to provide more continuous advice, based on fuller knowledge of the local situation, than are the consultants traveling from Mexico. In addition, CIMMYT outreach staff help select candidates for training in Mexico.

Collaborative Research in Association with National Programs

"Collaborative research" is a new activity in CIMMYT's core budget for 1975. CIMMYT and other international centers have found that a part of their assigned responsibility cannot be carried out at headquarters because the local environment does not provide the needed range of temperatures, moisture conditions, problem soils, or disease and insect conditions which affect the world crop. Therefore, some "core" research must be conducted abroad.

For example, the Potato Center (CIP) has found it cannot study late blight of the potato in Peru and has made arrangements for such research at the CIMMYT station near Toluca, Mexico, although it is charged to the CIP bud-

get in Peru. Similarly, IRRI has found it cannot experiment with deep-water rice in the Philippines, and it has arranged that such research be carried out in association with the Thai national rice program. Again, this is charged to the core budget in the Philippines and not considered as a service to Thailand.

CIMMYT has initiated two projects in "collaborative research" in 1975, one for the surveillance of wind-borne diseases of wheat-barley in the Mediterranean-Near East region and the other for the special testing of CIMMYT maize materials, in several areas of the world, for resistance to three diseases of maize not prevalent in Mexico. These diseases are maize downy mildew in Southeast Asia, maize streak virus in tropical Africa, and corn stunt virus in Central America.

One additional proposal for collaborative research, now under negotiation, is a summer season wheat nursery in cooperation with the Kenyan government at Njoro Station. A summer nursery could test CIMMYT experimental lines under the disease pathogens of the East African highlands together with some nursery materials from national programs in the Mediterranean region. This would help guide the breeding of CIMMYT and the national programs. CIMMYT staff posted in East Africa would also consult with wheat-growing countries in that area.

We anticipate that such activities will expand gradually over a five-year period to a magnitude of possibly $500 thousand a year. All will be conducted outside Mexico, generally in association with a strong national program.

Regional Programs for Groups of Producing Countries

During the remainder of the 1970s CIMMYT proposes to increase gradually its activities with national programs by stationing a few CIMMYT staff members in major producing regions to supplement the activities now conducted from Mexico. This expansion would be the most important change in the CIMMYT outreach program in this decade.

We have in mind six producing regions for maize and four regions for wheat, where staff may be stationed. Discussions have already begun with both governments and donors for the regions listed in Table 13-3.

No two of these regions are alike in population, internal transportation, quality of agricultural services, or production problems for wheat and maize. Nevertheless, CIMMYT calculates that, on average, two CIMMYT staff members placed in each of these regions (a total staff of twenty) could significantly help in the following activities: (1) serve as regional consultants to national programs; (2) maintain surveillance for wind-borne diseases in the region; (3) organize training within the region for national programs; (4) circulate nurseries composed of germ plasm gathered within the region and exotic materials; (5) organize regional workshops; (6) administer a travel fund for sci-

Table 13-3. Maize- and Wheat-Producing Regions Which CIMMYT Believes Will Need Additional Outreach Staff and Services in the 1970s

Region	Number of Countries	Present Production[a] (in tons)
Maize		
South and Southeast Asia	12	15,400,000
Tropical East Africa	14	6,400,000
Tropical West Africa	14	3,000,000
Central America and Caribbean (excluding Mexico)	9	2,300,000
Andean zone and tropical Brazil	6	7,400,000
Brazil	6	20,000,000
Wheat		
Mediterranean and Near East	15	23,900,000
East Africa	5	1,230,000
Andean region	5	337,000
Southern cone of South America	5	9,500,000

[a] 1973 figures.

entists in national programs to visit outstanding research in the region; and (7) circulate a regional newsletter.

Each regional program would go through three steps of approval before it began: first, CIMMYT would discuss with producing countries in each region the kinds of service required; second, CIMMYT trustees would be asked to approve the program; and third, financial support would be sought from a donor.

Problems and Issues in CIMMYT Outreach

Like all organizations that have experienced rapid expansion, CIMMYT encounters problems for which answers are still evolving. Several of these problems will be described below.

Regional and National Training for Production Agronomists

Centers with leadership responsibilities for one crop – for example, wheat at CIMMYT or rice at IRRI – have found it possible to provide the in-service training required for breeders, laboratory technicians, experiment station managers, and economists from national programs. The number of candidates in these fields is manageable.

But training for production agronomists (extension workers) involves hundreds of candidates in most countries and thousands in the larger programs such as those for India, Pakistan, Egypt, and the Philippines. Clearly

such training can best be organized within producing regions, or preferably within national programs, with some outside assistance provided by international centers. The cost factor alone would argue that this training be done at home, and the existence of various farming systems and various language problems also favors localization of training for agronomists.

Some experience is accumulating for regional and in-country training, but no reproducible system has yet been developed and the volume of training is still far from adequate. Some exploratory experiences are described in the paragraphs below.

1. When IRRI helped national programs introduce the first semidwarf rice varieties in the mid 1960s, IRRI organized training for extension workers within national programs on a three-step basis: first, IRRI brought to the Philippines a few extension leaders who would serve as trainers in a national program and gave them a course in rice production and in training methods; second, some IRRI training staff moved to the country where the training course was to be given and spent several months with the local staff developing the syllabus for the course and the demonstration crops; third, the local trainers and IRRI trainers jointly supervised the first course within the national program. The IRRI staff then withdrew, and further courses were wholly the responsibility of the local trainers.

This system was repeated in a number of national programs, generally just before the planting season for the crop.

2. The Rockefeller Foundation established regional training centers for wheat in Turkey and maize in Thailand, headed by Rockefeller scientists but also using trainers from within the host country. A considerable volume of training has been accomplished, especially by the Thailand center.

3. The Ford Foundation has financed a regional training program for a number of crops through the Arid Lands Agricultural Development Center (ALAD) at Beirut. One advantage of regional training, particularly for the Mediterranean region, has been that courses can be offered in the English, Arabic, or French languages for different groups of trainees.

4. Various bilateral assistance programs such as the United Kingdom's Ministry of Overseas Development (ODM), the Swedish International Development Agency (SIDA), Canada's International Development Research Centre (IDRC), and USAID have financed training programs for extension workers of various crops within national programs of the Mediterranean-Near East region.

5. CIAT has "trained the trainers" for several national programs of maize, rice, cassava, and beef in South America, then sent CIAT trainers to assist the local trainers in conducting the first in-country course. Such a course was co-

sponsored by the government of Ecuador and CIAT in late 1974 for the lowland agricultural area featuring rice, maize, beans, swine, and beef (all crops and animals for which CIAT holds responsibility).

The government of Ecuador has asked CIMMYT and CIP to repeat the same procedure for its highland crops, which include maize, wheat, barley, and potatoes. "Training the trainers" for this course has been completed at CIMMYT.

6. A totally different approach is represented by a Philippine-CIMMYT experiment in 1974. A top training officer for maize in the Philippines has spent a half year serving as the assistant maize training officer at CIMMYT. He has now returned home, carrying the CIMMYT work experience, but he gave us as much as he received.

Other formulas whereby the international centers can help organize more training for extension workers, in-country and in-region, will no doubt evolve.

The need is not yet adequately filled. That is a major reason why CIMMYT is proposing the assignment of trainer-agronomists to six maize-producing regions and four wheat-producing regions of the world.

Establishing Priorities: Need for Data

The international centers operated in the 1960s like horse-and-buggy doctors – diagnosing all problems with general information and common sense, and with surprising success.

Now, after the world crises in food, fertilizer, and energy have gained wide recognition; after more finances have been assigned to centers; after more national production programs have been organized – there is need for more quantitative information in making plans.

"Eyeballing" was a favorite term in the 1960s used to describe the methods for selecting new lines of breeding materials for crop improvement. Now more sophisticated methods of the statistician and the protein laboratory are supplementing the eyeball.

Our knowledge about national programs, their climates, and their governments was also relatively simple in the 1960s. "We worked on the problems that any cow could see from the side of the road" was a common expression. And at that stage of world cereal improvement the problems given the highest priority were also the most obvious.

Now, as the centers reach beyond the conspicuous problems and focus attention on constraints which were considered secondary ten years ago, more detailed information is needed about producing countries. However, the information needed for planning is not necessarily the same information which has traditionally been gathered and published by the FAO, the IBRD, and the USDA.

CIMMYT has begun, through the travel of its staff, to gather some of this information directly from national programs, and answers can be speeded by assigning postdoctoral fellows to some of this work.

We need information about cereal consumption: How many people eat bread wheat, durum, barley, or maize? What is the size of the demand for the different kernel types (flint, dent, floury) and colors of maize, and the different gluten strengths and colors of wheat? How large and populous are the areas where the total intake of protein is deficient and which could profit from hi-lysine maize and barley? What proportion of the LDC barley crop is used for human food, animal feed, and malting?

We also need a range of information about the extent not only of various climatic zones but of cropping areas affected by diseases and insects. Similarly, more information is needed on the extent and frequency of drought and on problem soils.

Answers to all these questions will become steadily more important in CIMMYT's program planning.

Problems in Management in National Programs

Deficiencies in management of national programs, especially in research management, constitute a frequent obstacle to improved food production. These management problems are common to all crops and all services, not just to wheat and maize.

Scores of crop scientists in developing countries, many with Ph.Ds, have left their home governments to join FAO or other international organizations. Their complaints against their home research service include low salaries, staff promotion on a political rather than a merit basis, lack of budget support from policy makers, corruption, and many other grievances.

Beyond staff losses other shortcomings in research management widely observed by CIMMYT consultants include the following:

1. Research managers try to handle too many crops and too many plant materials for each crop, resulting in unreliable data.

2. Research managers fail to test experimental plant materials off the station on private farmers' land, which would give a better understanding of what is impeding the farmers' yields and thus better guidance to research planning.

3. Research managers fail to identify elite plant materials at an early stage and to move these materials expeditiously into seed increase and varietal release for national use.

4. Research managers fail to arrange that the research organization perform a continuing training function for the extension service, by annual workshops at the research station, preceding each crop planting time.

5. Research managers fail to issue an annual report which is timely and objective, describing the status of national production each year and the constraints which are researchable, and discussing the relationship between the research service, extension service, seed increase agency, credit service, and other inputs needed to bring about higher yields.

Successful remedies to these management defects have been few, and the experience to date with international assistance for management has set no reproducible pattern.

Some countries with large food production programs like India, Pakistan, and Turkey appointed commissions to review the management of research in the 1960s. The success of such commissions has varied with the willingness of the Ministry of Agriculture to endorse the findings and support the director of research in making changes.

In 1973 the IBRD financed a mission to review the national research programs of Spain. This mission included a number of foreign consultants, including staff from two of the international centers. An earlier IBRD mission on agricultural education in the Philippines obtained a substantial improvement in the salary scale for those employed in agricultural research.

CIMMYT staff are often asked to comment on management problems in agricultural research and on the relationships between agricultural services in a national program. We have made no careful review of the actions taken after such consultation.

To date there has been no organized effort by the international centers to arrive at a judgment on the management problems in national programs, to list available consultants who could advise on management problems, or to incorporate a management component into the research training provided by the international centers.

14

Impact of International Research on the Performance and Objectives of National Systems

Sterling Wortman

The impact of international research on national systems may occur in a dozen or more ways, some direct and others indirect.

If we are interested – as we must be – in the impact of research on *entire* national agricultural systems, and hence on national agricultural productivity, we must also recognize that any effects of international research are confounded with those of many other technological, economic, and social factors. What portion of the overall effect is the result of research thus becomes a matter of judgment rather than measurement. And such judgments, to be valid, ought to be made by authorities of national systems who know firsthand the effects of research on their efforts. But, judgments by what authorities of what nations?

There are over 125 national agricultural systems: some are large and some small; some are centrally planned and others not; some are well supplied with trained people but most have few specialists; some operate with sizable or even liberal budgets but most have meager funds and facilities; some have a long tradition of distinguished agricultural research while others are just getting organized; and, finally, some belong to countries in which yields have been steadily advancing while others function where stagnation is characteristic. Assessing the impact of international research on such a complex of national systems, even if that assessment were made by a sizable panel of national authorities representative of these diverse interests, calls for consider-

able humility. Moreover, since the international system is so new (many programs are only two to five years old) and a lag of several years is to be expected in the application of research results, any current assessments must be accepted as tentative at best, with large error terms built in.

It is possible, however, to recall the ways in which the international research system was *intended* to affect national systems and even to describe in a general way what impact there appears to have been. Before proceeding to do this, it will be useful to consider definitions of some of the terms used in this chapter.

Definitions

By "national system" is meant the entire apparatus – public and private, from national governing bodies to the smallest farmer – which must be involved in the process of agricultural change. Included is the "national agricultural research system" with all its components, from the analyses involved in setting production and other goals (planning offices), through central and regional experiment stations and experimental programs of colleges or schools of agriculture, to on-farm experimentation.

Even the phrase "agricultural research" deserves definition. As used here it means the systematic effort to develop new ways to change agricultural productivity, or efficiency, at any level. Importantly, it includes the greatly underappreciated level of on-farm experimentation – assistance to individual farmers in identifying superior crop or animal production systems – a level of research which for too long has been miscategorized as "extension." It includes studies of ways to improve national planning and to identify rational agricultural goals, as well as the conventional field and laboratory work of experiment stations and colleges.

"International research" is here used to describe the total world experimental effort including that of (a) universities and agencies of developed nations, (b) international institutes and agencies, and (c) institutions of developing countries. From the standpoint of any particular nation, "international" research is all that is done elsewhere, plus the activities of any international organizations within its borders.

International Institutes

A substantial number of large and small, public and private efforts combine to affect in widely varying degrees the performance and objectives of national systems. As it is quite impossible in one chapter to examine the impact of such efforts, I shall limit my discussion to the impact of that relative new-

comer to the scene of international research: the autonomous, international agricultural research institute.

Research undertaken by the private but international institutes requires the special type of funding provided by the Consultative Group for International Agricultural Research. And, several unique characteristics distinguish research as it is conducted at the institutes:[1]

1. It addresses those complex problems that require long-term attention by teams of scientists backed by expensive facilities and that are not or cannot be handled quickly and effectively by other institutions.

2. It serves to fill important voids in international research and contributes to the development of a cohesive, collaborative world effort; hence, work at the centers gets its impetus and orientation in large part from others whose work it complements or backstops.

3. It provides opportunities for training at several levels of sophistication for the staff of national programs or from other institutions in the world system.

Confounding of Effects

Any impact on national systems by research at the international institutes is – and should be – confounded with contributions of research efforts elsewhere, since the institutes are simply hubs in an international network of cooperative, collaborative activity. Much of the centers' success depends upon the great array of advances made over past decades, upon the scientific and scholarly capital available to the centers in the form of advanced biological materials, equipment, or chemicals, and upon their store of knowledge and understanding as embodied in their staff and consultants or as given expression in their publications.

Success of the program of any international center is enhanced by the continuing flow into that center of the results of advances anywhere in the world. Indeed, one measure of success of a center is the degree to which it facilitates active exchange among nations of information and materials. The stronger the world effort a center helps to generate, the more successful we may judge that center to be.

The International "Network"

Probably the need for an international network, or world system, of agricultural research has been recognized and expressed many times in the past. Those working at the International Rice Research Institute in the early 1960s certainly had in mind the creation of an international *rice* research network;

in fact, the institute staff realized at the outset that its mandate – to increase national average rice yields and total production in Asia – would require the combined efforts of individuals and institutions of many countries. Without such a major cooperative effort – without the increase in yields and total production – the institute would be judged a failure. It was as simple as that.

Creation of a similar network had begun even earlier for spring-type bread wheats. The Oficina de Estudios Especiales of Mexico's Ministry of Agriculture, manned jointly by Mexican and Rockefeller Foundation scientists, was at work on this in the late 1940s, when young technicians and scientists of other countries were brought to Mexico for training, and a system of international cooperative field trials was organized. At about the same time similar efforts were initiated with maize, and in 1954 the Central American Cooperative Corn Program was launched, with agencies of all nations of Central America and Panama participating.

There were early international efforts with some crops sponsored by FAO through FAO-Rome and the International Rice Commission, by USDA, and probably by others.

By 1969, the need for a comprehensive international research network had been recognized by the Rockefeller Foundation, and the concept was presented to the heads of the world's assistance agencies at an April 1969 meeting in Italy (now referred to as "Bellagio I" in agricultural circles):

> Action Recommended
>
> Acceleration of world agricultural output can be fostered by the formation of a worldwide, interlocking complex of national and international scientific institutions, programs, and projects designed to produce scientific information, materials, and manpower required to intensify agricultural production wherever needed. Provision must be made for immediate attention to all areas where agricultural productivity is still low and static and where man:land ratios are most unfavorable, and to control of many internationally serious diseases and pests. The underexploited tropics and certain arid areas can and should be brought into use as required.
>
> Development of such a network of institutions and activities will require that national and international efforts be cooperative and coordinated to the extent possible. Toward this end, increased and periodic dialogue among appropriate leaders should be established, to identify neglected, high-priority needs and to foster cooperation wherever indicated.[2]

The foundation's paper went on to list and discuss some of the necessary components of an international network, including (a) international centers

(such as IRRI, CIMMYT, IITA, CIAT), (b) regional research centers, (c) international programs and projects, (d) national research, training, and production systems, (e) colleges of agriculture, and (f) centers of specialization in developed nations.

In a summary statement in the above-mentioned proceedings, prepared by the late Dr. W. M. Myers, the participants recognized the need for support of an international "hierarchy of institutions" and for mobilization of large sums of money for investment in high-technology agriculture.

The elaboration of such a system, with favorable impact on yields, quality, and total production of major food crops and animal species in the developing countries, is the central concern of the Consultative Group for International Agricultural Research.[3] An impressive beginning has been made.

Effects and Interactions

The newly developing international research effort has had a multiplicity of effects on national agricultural systems, on national research programs, on production of certain crops in some regions of the world, and on foundations, national assistance agencies, and international institutions. As we have already noted, there is a high degree of interdependence (the confounding effect mentioned earlier) among these varied organizations, and the fact that they are discussed separately below should not cause us to lose sight of that. Perhaps a few examples of the simpler interactions will be helpful. First, the clear demonstration that new opportunities exist to raise yields and the profitability of farming can cause agencies to invest in new initiatives. Similarly, the decisions of national authorities to push the production of particular crops or animals in particular regions influence the orientation of research.

Second, experimental evidence that large numbers of small farmers can be benefited through promotion of high-yielding cropping systems probably has had an impact on international agencies such as the World Bank. Surely the World Bank's decision to promote increased productivity of small farms will affect research and production efforts of many nations and most international centers.

Third, success or lack of success of national production programs utilizing technology developed locally or internationally will in turn have an effect on the orientation of efforts at international centers.

Fourth, breakthroughs at centers of specialization, including universities, can have far-reaching consequences. For example, the identification at Purdue of the opaque-2 gene effects in corn and Purdue's discovery of lines of sorghum with high nutritive value are having an obvious impact on the research programs at CIMMYT and ICRISAT, as well as on national programs.

Fifth, determinations of the payoff from investment in agricultural research and of the factors which influence such payoff will surely have an effect on investment attitudes of international banks and assistance agencies and, it is hoped, on the leaders who must make national decisions regarding investment in agriculture.

There are many other interactions which might be mentioned, but the foregoing may suffice to demonstrate that interdependencies exist. Studies of factors conditioning the effectiveness of agricultural research can, if constructive, lead to improvements in such research efforts.

Impact on National Systems

In their studies of the impact of international research on the performance and objectives of national systems, some investigators have attempted to identify specific causes and effects as well as potential improvements in the direction or operation of the systems. Almost invariably, such studies require not only narrowing of the issues and the employment of assumptions which may or may not be correct but also the exclusion of some considerations which are so elusive that they cannot be adequately considered. Let me mention a few of these elusive problems.

First, a substantial number of leaders from the developing nations serve on the boards of the international institutes, on the Technical Advisory Committee of the Consultative Group, or as representatives to the Consultative Group. Others are on boards or advisory committees of international banks or international or national assistance agencies. In such roles they participate in a continuing debate on approaches to the development of agriculture and become acquainted with advances in materials or techniques as they occur. Undoubtedly this experience has an impact on the performance and objectives of these leaders' respective national research systems, but how does one measure such impact?

Second, through participation in the various Bellagio conferences which led to the formation of the Consultative Group, through service on the boards of institutes, and through their interactions with leaders of developing countries, the heads of assistance agencies have become increasingly knowledgeable, and some have made major changes in their approaches to lending and/or to providing technical assistance to developing nations. These changes can have an impact on the nations themselves. But it is impossible to quantify the magnitude and effect of such changes, and consequently it is difficult to attribute them to any set of institutions.

Third, the construction of modern agricultural research centers in Africa, Asia, and Latin America has drawn the attention of national political leaders,

of both developed and developing countries, to the importance of agricultural research. That such installations were placed in the developing countries certainly has demonstrated in a dramatic way that many of the biological components of agricultural production systems must be developed in and tailored to the ecological and economic requirements of the regions where they are to be utilized. An impressive number of heads of state and ministers of the developing countries have been drawn to these modern centers. That this has had an effect on the quality of facilities provided in some nations, for both research agencies and universities, is without doubt. To trace such effects would be difficult; to suggest probable causes would be risky at best.

Fourth, we have witnessed the strengthening of national agricultural institutions, the initiation of production campaigns, the implementation of decisions to work with small farmers, and the reorientation of activities of universities and national agencies. But the degree to which such decisions have been affected by the international research system is and probably will remain unknown.

Fifth, during the past several years, the Ford Foundation has greatly increased its intellectual and financial involvement in agricultural research. The International Development Research Centre of Canada has been formed and has become an important source of research support and innovation. These and other organizations with a longer history of involvement, such as FAO, USAID, the United Kingdom's ODM (Ministry of Overseas Development), France's ORSTOM (Office de la Recherche Scientifique et Technique d'Outre-Mer) and IRAT (Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières) and the ADC, have participated in a growing international effort to improve understanding of systems, to add to the knowledge base, and to foster the exchange of information among interested individuals and institutions. It all adds up to a growing world capability, with important but immeasurable effects on national programs.

Given these and other influences of unknown magnitude on national programs, we can only point out – we cannot measure – some of the probably important ways in which the international research system has had an impact on the performance and objectives of national efforts.

Impact on National Agricultural Systems

Clearly the international research system has drawn attention worldwide to the importance of agriculture. Some of the early successes, notably those with wheat and rice which were popularly termed the "green revolution," attracted the interest of national authorities. Visits to the centers by national leaders probably created in some the desire to promote scientific agriculture

at home, to strengthen national research agencies and universities, and to marshal the necessary funds for research and production efforts.

In the late 1960s, the long-neglected basic food crops (cereal grains, food legumes, root crops, vegetables, animal species) began to receive serious consideration by many nations. It was recognized that work on these crop and animal species would have to be done in the public sector; there simply was no way for private companies to realize returns on investments in such activities. Clearly the present focus on production of the basic food crops in the developing countries is in part attributable to such an emphasis at the international institutes.

There has been a recent trend toward production-oriented, commodity-oriented research and production programs in a number of nations. While not replacing discipline-based research, the new trend reflects the more purposeful nature of new national activities.

There has been a growing realization of the need for more sophisticated agricultural research efforts at the farm level.

The institutes offer new sources of training for research and production personnel from national institutes. More and more often the much sought-after, high-quality educational programs offered by universities in the United States, Europe, and elsewhere are being combined with graduate thesis research at international centers or in the developing countries. This has permitted graduate students to contribute to the solution of problems of the regions in which they live. Specialists or advisers at such universities have become engaged in this work on developing nations' problems, and many lasting friendships have been formed among institutions and individuals – relationships which will be of growing importance. Surely the new forms of training have had and will continue to have a major impact on the strength and the orientation of developing countries' institutions. But, again, effects of training would be hard to measure.

Finally, the successes of new production programs, together with the continuing need to increase agricultural output, have contributed to the growing willingness of some nations to increase their investments in scientific agriculture.

Apparently there is a growing conviction among national leaders that science-based agriculture (plus reduction of population growth rates) offers the only reasonable hope of meeting food needs and raising the standards of living of the rural poor; this must to some degree have been stimulated by the international research system.

Impact on National Research Systems

International research efforts clearly have affected national research systems in ways other than the production of useful technology and trained people.

Priorities established for the international system by the Technical Advisory Committee of the Consultative Group control in a major way the priorities of the international institutes and of related programs. Advanced technology available through the institutes and through the types of training they offer in turn affects the priorities of national organizations.

The production orientation of much of the international research effort, including its emphasis on commodity-oriented research, evidently is gaining acceptance as a logical approach by increasing numbers of nations.

The interdisciplinary team approach to problem solving is spreading. The larger nations can and must undergird their production-oriented research efforts with more basic investigations. The greater number of the smaller nations, however, cannot expect to organize truly comprehensive scientific efforts right now. In the immediate future, the in-depth, interdisciplinary research at the international centers will serve as the more basic research effort for these nations, allowing them to concentrate their limited human and financial resources, as they should, on the tailoring of technology to their own needs and in getting it applied at the farm level. At the same time, we must note a growing sophistication of the agricultural research effort of some nations, which undoubtedly is due to the influence of the international cooperative activities.

New standards of performance are being set. Everywhere there is growing dissatisfaction with the low and static yields so generally being obtained, and scientists are being pressed to do something to raise these yields; this is an issue that no longer is easy to duck. Scientists now freely discuss and compare yields per hectare per crop, per hectare per year, and even per hectare per day. The new higher yields are being demanded by people outside the scientific fraternity, and this is a healthy development.

Research programs are being speeded up – more problems solved, more new materials produced. Two or sometimes three experimental crop generations are grown per year.

More frequent opportunities now exist for national scientists to meet with colleagues from other institutions in their home countries, from institutions in other countries, or from international institutes. This helps to prevent the repetition of experimental work already accomplished elsewhere. Through international conferences innovation is fostered. It is likely that such opportunities for exchange of ideas and information will help to attract and hold competent national researchers on the job.

International cooperative experiments and field tests draw the community of scientists together, allowing them to base conclusions on much more substantial experimentation than would otherwise be possible. By testing new materials and techniques over many locations in a single year, the time required to generate necessary data is shortened. For these and other reasons,

one can sense a dramatic acceleration in the world drive toward an improved science-based agriculture.

The international institutes have introduced an element of stability into the world research effort. None of the major assistance agencies, with the possible exception of the World Bank, could arrange with any degree of certainty for the long-term maintenance of an international center. But multilateral support of such efforts provides reasonable security for such operations. The presence of substantial numbers of career scientists at the international institutes ensures that continuing contributions to the world knowledge-base will be centrally preserved, not lost as so often occurs when research efforts are of short duration and participants scatter. Even when national research operations are disrupted for political or other reasons, momentum can be regained more easily if the national agencies have been cooperating with an international center. One reported example of this was the resumption of activity of the Bangladesh Rice Research Institute following the civil war. The fact that IRRI had been involved, along with others, allowed BRRI to pick up its program and move ahead when conditions again permitted it. Stability is an important factor in the world effort, but how does one measure its impact?

Impact on National Production

Clearly the international research effort has had a positive impact on national food production. National and international agencies are attempting to measure it. Dalrymple has provided extraordinarily valuable assistance in monitoring the spread of high-yielding varieties,[4] and a number of investigators have studied the effects of research on levels of production. Indeed, the presence at Airlie House of so many capable people reporting on significant work was testimony to the growing impact of research. Yet we are all aware of the difficulties of isolating the effects of research on production, given the many other factors which obviously are involved.

Impact on the International Community

There is a growing understanding of the requirements for increased agricultural output per unit area per unit of time. That understanding is spreading, albeit too slowly, through the staffs of national and international organizations. Gaps in technology are being identified and, rather systematically, closed.

We seem to be moving toward the identification of strategies of national agricultural development that are much more likely to succeed than were the earlier ones. Moreover, the newly developing acquaintances among individuals and institutions have added an element of mobility to world scientific efforts. The impact on the developing nations should be favorable.

Schultz pointed out several years ago, in his excellent book *Transforming Traditional Agriculture*, that the small farmer is a rational economic being, that he is efficient in the management of scarce resources, and that he will in many cases improve his farming practices if it is feasible and profitable for him to do so. And now at last interest in the small farmer is gaining momentum.[5] In part this is the result of work carried out with some support from international centers: the Puebla Project in Mexico; IRRI's research program in central Luzon, which reportedly has contributed to the government's "Masagana 99" program. The impact of such activities on the decision of the World Bank to press for small farmer programs is unknown to me. But, out of the growing debate on the feasibility and desirability of assisting small farmers has come the realization that they *must* become involved. They can contribute significantly to increases in needed food output. If improvements in their own incomes occur, they can purchase the products of urban industry, thereby increasing the domestic market for those products. In short, the improvement of the productivity and incomes of small farmers in most countries should provide new momentum to the economic development of those nations.

Certainly those involved in the international research network have made a significant contribution to awareness on an international scale of small-farmer problems and potentials. But the task of measuring the magnitude of any such contributions is difficult, if not impossible.

Measuring Magnitude of Impact

In the preceding sections I have attempted to identify some of the contributions which have been made by the international research system.[6]

The next logical question is, What has been the *magnitude* of the impact? The answer is easy: I don't know. The Airlie House conference did not fully answer the question, though it surely has moved us closer to a sound judgment.

Many of the probable effects of the international system are elusive (but not phantom) and are cumulative in their effects, hopefully in a positive direction. My guess is that the effects of the international system on national systems generally will be greatly underestimated, especially in studies in which scientific methodology is rigorously and correctly applied. Error will occur because of the difficulty of sorting out interdependencies required to arrive at net effects. In all likelihood, calculations will be off by several orders of magnitude. However, this should not discourage us from attempting to reach ever better approximations.

Meanwhile, the elaboration of the international system and of most national systems will continue to be based on judgments. There is no alternative, for decisions must be made. People are hungry, populations are growing,

and time for effective action is passing. Fortunately, new mechanisms have emerged for arriving at considered judgments, and in the following paragraphs a few of these will be mentioned.

There is a growing number of national authorities, including scientists, who have been watching national development long enough to have witnessed change and who are aware of major factors causing such change. In 1972 the International Rice Research Institute, after ten years of operation, arranged for several people to review the impact of the institute and its work.[7] Three of the participants in that conference had particular competence to evaluate IRRI's contributions. These were Dr. D. L. Umali, now assistant director general for Asian and Eastern Affairs, FAO-Bangkok, and formerly dean of agriculture of the University of the Philippines; Dr. B. P. Pal, who served as director general of the Indian Council of Agricultural Research through the 1960s; and Dr. Gelia T. Castillo, associate professor of rural sociology, College of Agriculture, University of the Philippines. Their papers are very useful and should be read widely by people outside the institute.

A more formal assessment of impact is made by the board of directors of each independent institute. Institute directors are aware of national needs and know how importantly international research efforts may influence, or fail to influence, the efforts of their nations.

The impact of the international system is under constant review by the Technical Advisory Committee of the Consultative Group either through the efforts of its own members or through the review missions which it organizes.

The effect of the international system on national programs is under continuing review by the donor organizations which compose the Consultative Group. These organizations are investing substantial sums of money in the system and are under presssure to provide justification for those investments.

Finally, there are the studies of the impact of the international system undertaken by investigators such as the Airlie House conference participants. These provide a valuable basis for the judgments which must and will be made by individuals whose responsibility it is to make decisions.

Quantitative assessments of the impact of the international system on national research and production efforts clearly cannot be precise. However, judgments on the organization of and investment in research are, one hopes, increasingly based on the more solid information being generated and certainly can be based on a growing body of experience. There is comfort in that.

NOTES

1. For an elaboration of this subject, see "The International Agricultural Research Institutes: Their Unique Capabilities," *Rice, Science and Man* (Los Baños: International Rice Research Institute, 1972), pp. 65-75.

2. See "The Technological Basis for Intensified Agriculture," *Agricultural Development: Proceedings of a Conference Sponsored by the Rockefeller Foundation, April 23-25, 1969, at the Villa Serbelloni, Bellagio, Italy* (New York: Rockefeller Foundation, 1969), p. 39.

3. For a brief history of the development of the Consultative Group, see Sterling Wortman, "Extending the Green Revolution," *World Development*, 1:12 (December 1973), 45-51.

4. Dana G. Dalrymple, *Development and Spread of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, Foreign Agricultural Economic Report no. 95 (Washington, D.C.: Economic Research Service, USDA, 1974).

5. See Carroll P. Streeter, *Reaching the Developing World's Small Farmers* (New York: Rockefeller Foundation, 1973).

6. For a discussion of effects on crop research, see Sterling Wortman, "A New Era in Crop Improvement," H. K. Hayes Memorial Lecture (Minneapolis: University of Minnesota, 1974).

7. The collection of papers was published in *Rice, Science and Man*.

15

Impact of the International System on National Research Capacity: The CIMMYT and IRRI Training Programs[1]

Burton E. Swanson

This chapter examines the impact of the different training strategies being employed by the International Maize and Wheat Improvement Center (CIMMYT) and the International Rice Research Institute (IRRI) to help build research capacities in less developed countries.

It is necessary first to clarify how research capacity is being viewed here. Ruttan and Hayami considered the problem of international technology transfer and differentiated the process into three phases: (1) material transfer, (2) design transfer, and (3) capacity transfer.[2]

The international transfer of wheat and rice technology during the late sixties was largely in the "material transfer" stage. Many developing countries imported substantial amounts of seed during that period.[3] At the same time "design transfer" was also occurring, as national research institutions began to receive new, high-yielding experimental lines and varieties of wheat and rice that were then tested and, in some cases, multiplied and released to agricultural producers.[4] In addition, the international research centers, through their training and outreach programs, were beginning to devote some attention to the third phase of the technology transfer process. However, "capacity transfer," or building a national research infrastructure that can produce scientific knowledge and improved agricultural technology – and adapt it to local ecological, resource, and institutional conditions – has been found to be a slow, difficult, and complex task.[5]

To understand better the institution-building task associated with capacity transfer, it is useful to differentiate research capacity into its two primary functional components: science and technology. Price developed some generalized definitions, during a parallel discussion on technology transfer in space science, that are useful to this discussion: science is taken to be those research activities that result in scientific papers being written and published; technology is "that research where the main product in not a paper, but instead a machine, a drug, a product, or a process of some sort."[6]

The point in making these rather sharp distinctions between science and technology is not artificially to separate one part of this process from the other or to suggest that research workers should work in only one area or the other. Many agricultural research workers function in both knowledge-generating (science) and technology-developing roles and move easily and effectively between them. But in organizing national research institutions there has been a tendency to overlook the technology-development function. Wortman has made this point rather succinctly: "That agricultural research must be undertaken at central experiment stations or in the laboratories of national research organizations or colleges of agriculture is well understood; frequently, however, the further steps of identifying and testing packages of technology in each distinct farming region of a nation and finally at the ultimate experimental site – the individual farm – are erroneously excluded."[7] Because of the importance of this distinction we need to know which hat a research worker wears at any one time in order to understand the thrust of his overall research program and how it contributes to national research capacity.

Before proceeding in this discussion, I wish to present the concept of the *biological architect*, as utilized in this chapter. The biological architect is the high-level research worker who develops improved biological technology. He is the "master builder,"or the "research inventor," who manipulates and integrates new and/or different factors, materials, knowledge, etc., to create improved agricultural technology.[8]

Scientists and biological architects use many common research tools, but differences in research objectives and output demand substantially different types of cognitive behavior. The scientist, in his pursuit of new knowledge, engages primarily in analytical research. *Analysis*, as a cognitive skill, "emphasizes the breakdown of the material into its constituent parts and detection of the relationships of the parts and of the way they are organized."[9] The scientist uses research tools as a means of testing specific hypotheses that result from his analytical inquiry.

The biological architect engages largely in creative thinking and, by trying new materials and methods in different combinations and amounts, attempts to develop new technology or technological components that will better

achieve a production objective (such as increased output, reduced risk, or reduced costs). In terms of cognitive behavior such creative thinking may be characterized as *synthesis*.[10] In synthesis, the research worker "must draw upon elements from many sources and put these together into a stucture or pattern not clearly there before. His efforts should yield a product. . . ."[11] The biological architect uses research tools to evaluate his newly created technological combinations or components in order to determine their production potential.[12] Perhaps it is because the biological architect must spend so much of his time evaluating his new technological combinations and components – through the use of relatively simple and routine research trials and tests – that the importance of his intellectual or cognitive contribution has been overlooked or minimized.

Applying this framework to research capacity as it relates to crop technology, we see that in the past it has been the plant breeder who has generally developed improved genetic technology by manipulating different genetic factors to produce improved varieties. The production agronomist has developed and refined improved production recommendations for use by farmers by manipulating new and/or existing factors of production (such as improved varieties, fertilizers, pesticides, cultural practices, etc.) in different ways. In more recent years, as agricultural technology has become increasingly sophisticated and complex, the trend has been to form interdisciplinary research teams which work together in manipulating and integrating different chemical, biological, or mechanical factors of production to build superior agricultural technology.[13]

Before moving into a discussion of the training strategies being used by CIMMYT and IRRI and the impact of these strategies on research worker behavior and research capacity, we should mention one other institutional factor that appears important to the question of science and technology and the process of building national research capacity. This factor is the predominant reward system within agricultural research that appears to be exerting significant and continuing influence on research worker behavior and national research capacity.

Reward Systems in Agricultural Research

One explanation why research institutions in many less developed countries have been ineffective in producing improved agricultural technology is that research workers have tended to concentrate on more theoretical research problems rather than working to solve farmer production problems.[14] An hypothesis that is logically consistent with and will explain this behavior is that agricultural research workers in LDC's have adopted or internalized the

normative structure of the public research establishment (the university and the corresponding academic/scientific professions) of industrially developed countries.[15] The following factors serve to support and elaborate on this hypothesis.

First, most research workers in the LDC's with advanced degrees received their academic training in foreign universities, primarily in the United States and Europe. Many of these research workers may have been influenced by the "publish or perish" reward system that is common to large, research-oriented colleges of agriculture in the United States. Furthermore, because advanced research degrees require an "original" research inquiry that contributes to the body of knowledge in the respective discipline, these research projects are frequently highly specialized and theoretical in nature. Both of these factors could tend to orient young research workers toward more theoretical, scientific inquiries.

Second, in the United States the knowledge-generating research function (science) is carried on primarily within the public sector (universities), whereas the greater part of technology-developing research is carried out in private industry.[16] Although research workers who conduct technology-development research have much less opportunity to publish in scientific journals and to gain professional recognition from their colleagues than do their counterparts in the public sector, salary schedules in private industry have traditionally been higher than those in public research institutions. Thus, in the overall agricultural research system of the United States, there is to some extent a trade-off between professional and economic rewards. Research workers, depending on their interests, abilities, and what they consider to be important, have alternative career patterns they can pursue.

On the other hand, in LDC's most if not all of the national agricultural research capability is located within the public sector, generally within a ministry of agriculture or university. Therefore, the opportunity for research workers to select between economic and professional rewards is quite limited. Agricultural research workers receive salaries according to the bureaucratic procedures and criteria being followed by the research institution, not according to the type of research carried on. Therefore, there is no potential within the research institution itself for inducing research workers (through economic rewards) to pursue career patterns oriented toward technology-development research objectives.

Thus, in the absence of an alternative reward system, it appears inevitable that professional rewards will take on increasing importance in influencing the types of research activities being undertaken by research workers in LDC's, particularly given the considerable professional recognition associated with publishing in a prestigious scientific journal with an international clientele.

Third, in most cultures agricultural work is considered a low-status occupation; therefore, there are no positive social rewards to encourage a highly trained research worker to work on practical problems – the results of which would be of direct importance only to a peasant or cultivator and which would not result in any significant professional recognition. Even if individual scientists were motivated to do this type of research, the research organization has no effective way formally to reward these successes.

Finally, the spirit of cooperation is frequently missing from national research institutions, and scientists may tend to think about achieving personal rather than institutional credit. To develop improved agricultural technology requires considerable interdisciplinary cooperation, but the credit accrues to the team, not to the individual. If this team credit is usurped by the research director or the team leader, instead of being shared by the team members, individual research workers will not be encouraged to work together on future endeavors.

All these factors may prompt agricultural research workers in LDC's to concentrate on individual research projects aimed at generating new knowledge where they can receive professional recognition and rewards directly. In most national research systems in LDC's there are too few positive rewards and incentives to encourage research workers to carry out technology development. It is no wonder, as Singer suggests, that the meager research resources of the LDC's (estimated at 2 percent of the world's research and development expenditure) are frequently misdirected to research problems that are more relevant and useful to the rich nations.[17]

The CIMMYT Wheat Training Program[18]

The wheat training program in Mexico is an integral part of CIMMYT's program for making improved wheat technology available to farmers in all major wheat-growing regions of the Third World. Strong national programs are an essential part of this international wheat improvement strategy, both in the process of developing and disseminating improved wheat technology and in dealing with spin-off problems, primarily disease epidemics, that are a potential threat to the precarious food balance in populous nations.

When the wheat revolution began to spread to South Asia and the Middle East in the early sixties, national wheat improvement programs in these areas were generally weak and poorly organized. Training programs were used by CIMMYT to upgrade the technical skills of research personnel in an attempt to build strong, independently functioning national programs that are nevertheless interdependent with other national programs and with CIMMYT for new genetic resources and technical information.

At all levels, CIMMYT stresses a "team" or integrated approach to wheat improvement. At the program level, the emphasis is on interdisciplinary teams. At the international level, the national programs and CIMMYT work together as part of an overall international wheat team systematically to share not only superior germ plasm and new varieties as soon as they are developed but also technical information on these genetic materials.

The wheat training program is directed primarily toward middle-level research workers. The program revolves around three main educational objectives: to impart to trainees the research skills and knowledge needed to run a wheat improvement program; to encourage and develop the trainee's ability to create (synthesize) new forms of wheat technology; and to foster specific types of attitudinal change among trainees.

Technical Research Skills

The first half of the regular eight- to nine-month training program in wheat improvement deals largely with the mechanics of running an efficient, well-organized research program. Trainees learn all the essential research skills and techniques needed to manipulate and evaluate new forms of wheat technology through "on-the-job training."[19] Trainees follow the CIMMYT wheat program through each stage of the growing season (and the varietal development process) with each task or operation first being discussed in the classroom and then demonstrated in the field. After the trainee has had the opportunity to practice the skill and is "checked out" to ensure that he is reasonably proficient, he proceeds to help carry out each research task or operation within the ongoing CIMMYT research program.

Technical Research Ability: Synthesis

Once the trainee learns the methodology and procedures of operating a research program he can give increasing emphasis to the genetic materials passing through the research program. For example, the job of the breeding team is the creation, or synthesis, of new genetic lines and varieties by combining and recombining diverse types of germ plasm. To be effective and efficient in developing improved high-yielding varieties, the trainee must learn and become increasingly familiar with the various genetic characteristics and materials he is attempting to manipulate. For example, an experienced biological architect in the CIMMYT wheat program can walk up to an advanced generation plot – and there are hundreds of such plots – and from visual inspection alone give the approximate pedigree of the line (from several hundred potential parent lines and varieties), give several reasons why the cross was made, and evaluate the line for those visual characteristics. By working side by side with experienced biological architects in the CIMMYT wheat program, and by asking and

being asked the question, "why?" trainees soon begin to develop an ability and an insight into the creative process of genetic engineering.

Attitudinal Objectives[20]

There is a common expression used in the CIMMYT wheat training programs: "The plants are talking to you, but you have to use your *eyes* to hear what they are saying." In other words, wheat plants being grown under a variety of different conditions respond differently to those conditions. A good observer is able to detect how plants react to each of these different environmental conditions and, based on all these data, select those genetic lines with the greatest potential.

CIMMYT seems to use a similar selection technique for its trainees. For example, CIMMYT has been criticized by some visitors to the training programs in Mexico for "using" trainees for such routine tasks as inoculating the segregating, or F_2, populations with rust spores. This is a job that CIMMYT needs to have done and requires about ten days to two weeks of hard, back-breaking work, wading through muddy plots (many times in the rain) and injecting two tillers of each F_2 plant with a syringe full of disease inoculum.

After the first morning of this activity, there is no additional technical training value to be accomplished; however, what the CIMMYT staff learns about the "trainee population" during these two weeks is very important. Some trainees can disguise their displeasure at this type of work for a morning or two, but after a week or ten days, trainees are clearly differentiated by their "reaction to hard field work." Some trainees may do the work while CIMMYT staff members are nearby, but then relax under a tree when the latter leave. A few may call in sick for a few days to avoid work. Others, however, are out in the plots getting the work done. It is this last group that CIMMYT particularly wants to identify. CIMMYT believes it is this group that will begin to make up the hard core of working scientists within the national wheat improvement program.

The training program in Mexico is viewed by the CIMMYT wheat team as only the first step in a long-term process of building effective wheat research workers and national wheat improvement teams. Because of this long-run perspective, the training program becomes both a manpower development tool for training skilled research technicians and an "early generation" selection tool for identifying potential biological architects. Trainees are observed in Mexico and again back home on the job. Those who excel in attitude, outlook, intellectual ability, and technical know-how in both working environments are identified as prime candidates for academic fellowships. It is hoped that these individuals, given additional educational opportunities, will become

Table 15-1. Average Number of Research and Production Activities Completed by Those CIMMYT Wheat Trainees Who Were Active in Wheat Improvement Programs during 1972

Type of Activity	Trainees Conducting Each Activity (N = 105)		Average Number Completed per Trainee (N = 105)
	N	%	
Laboratory or greenhouse experiments	13	12.4	1.37
On-station field experiments	56	53.3	5.62
Genetic crosses	56	53.3	227.1
On-station replicated applied research trials	65	61.9	7.24
On-farm replicated applied research trials	44	41.9	4.74
On-farm high-yielding production plots	37	35.2	3.71

key biological architects in their own national wheat improvement programs in years to come.

Results[21]

Approximately 82 percent of CIMMYT's former trainees are still actively engaged in wheat research and production activities, with another 8 percent being indirectly or partly involved in wheat improvement work. Only about 10 percent of former CIMMYT wheat trainees are no longer working in wheat improvement programs.

As shown in Table 15-1, the performance of those former participants who are still engaged in wheat research and production programs (105 trainees of 130 total respondents) is high, as measured by the numbers of research experiments, replicated field trials, genetic crosses, and production plots completed. Furthermore these trainees are emphasizing technology development, as opposed to experimental research, particularly in the area of genetic technology.[22] It appears that the work of CIMMYT trainees, once back home, is quite consistent with CIMMYT's training objectives.

CIMMYT appears to be very effective in producing research workers who can develop improved genetic technology, but it has not had as much success in producing the other half of the wheat improvement team, the workers who can develop the complementary package of practices. This weakness probably stems from the fact that the CIMMYT research program concentrates on widely adapted genetic technology, with production technology being viewed as a location-specific problem. The fact remains that wheat production agron-

omists are sorely needed in most national programs to develop appropriate production recommendations that will enable farmers to exploit fully and economically the production potential of the superior varieties being developed.

The IRRI Training Programs

IRRI's programs for research training and rice production training make up the major part of its training activities. The impact of these programs on national research capacity is described and analyzed here.

IRRI Research Training Program

IRRI is committed to strengthening national rice research programs, and its leaders see the research training program as a resource that national programs can use in upgrading the technical proficiency of their staff members.

IRRI's research training approach centers on the research project. Trainees are expected to focus on a serious production problem in their home country and to carry out one or more research projects that will generate new knowledge and possible solutions to these problems.

Research trainees work closely with a senior IRRI scientist and frequently carry out projects that are an integral part of their adviser's overall research. In some cases these research efforts result in jointly authored papers that report important research findings and contribute to the growing body of knowledge about rice production in the tropics.

Although some advanced research trainees come to IRRI to learn specific research skills and techniques, or to conduct projects that are beyond the scope of their national programs (because of the lack of adequate scientific equipment), the major objective of the project approach is to provide participants with a solid research experience – teaching them each step involved in planning, designing, executing, and reporting on a research project. At each step of the way, trainees learn by doing. In terms of educational objectives, the major focus of the project approach is on *analysis* and on using research as a tool to generate new knowledge about production problems and their possible solutions and/or to test suspected relationships between production factors. The knowledge that is generated from these projects may be used in the development of improved rice technology that will increase rice production in the tropics.

There are two exceptions to the project training approach: (1) Nondegree trainees in varietal improvement do not conduct research projects but work largely as research assistants in IRRI's ongoing rice-breeding program. Again, these trainees learn by actually carrying out each task involved in a varietal

improvement program, and at the same time they become familiar with the germ plasm currently being used in the IRRI program. (2) Agricultural engineering technicians are given short-term training so that they can evaluate and demonstrate IRRI-developed machinery in their own countries under local conditions.

Each research trainee works primarily in a single department at IRRI, but the Saturday Seminar provides the institutional mechanism by which both trainees and staff learn of recent research findings in other departments. By sharing research results with staff members in other disciplines, scientists can frequently gain new insights and perspectives on important rice production problems which may lead to cooperative efforts between departments. Such multidisciplinary efforts demonstrate to trainees how an effective research institute can organize its scientific resources in alternative ways to accomplish different objectives.

The institute is conveniently located next to the University of the Philippines' College of Agriculture, and about one-third of IRRI's research trainees combine an M.S. degree program at the college with research training at the institute. IRRI scientists believe that combining a degree program with a solid research experience enables trainees to perform more effectively after returning home and also gives them the necessary educational credentials to move into leadership positions in their respective national programs. In general, IRRI research trainees are a highly educated group. At the time the participant follow-up survey was taken in 1973, 41 percent of the research trainees had M.S. degrees, 43 percent had either received or were working toward Ph.D. degrees, while only 16 percent of the group were still at the B.S. degree level.

Results

Former IRRI research trainees reacted in very positive terms when assessing their training experience at the institute. IRRI selected both research and teaching personnel from national institutions, and more than 90 percent of all research trainees indicated that the training had been of some or full use to them since returning home. In addition, approximately 71 percent of former trainees (who were working when the survey was taken) were still actively involved in rice research or production programs.

In considering the main educational objective associated with the project training approach (i.e., analysis), it seemed consistent to expect trainees to continue working in experimental (analytical) research after returning home. To test this hypothesis, the work behavior of former trainees was examined to determine which types of research were being emphasized (see Table 15-2). As expected, more knowledge-generating types of research (field, laboratory, and greenhouse experiments) were being carried out than research activities

Table 15-2. Average Number of Research and Production Activities Completed by Those IRRI Research Trainees Who Were Active in Rice Research and Production Programs during 1972

Type of Activity	Trainees Conducting Each Activity (N = 154)		Average Number Completed per Trainee (N = 154)
	N	%	
Laboratory or greenhouse experiments	65	42.2	1.61
On-station field experiments	85	55.2	3.48
Genetic crosses	46	29.9	19.9
On-station replicated applied research trials	57	37.0	1.55
On-farm replicated applied research trials	38	24.7	1.17
On-farm high-yielding production plots	39	25.3	1.46

associated with the direct development of rice technology (agronomic field trials and genetic crosses).[23]

Another factor considered in determining the type of research being emphasized by IRRI trainees was the form of research output, particularly since research papers are the primary output from knowledge-generating types of investigation. First, it was found that 106 research trainees had been able to publish (or present) a total of 187 research papers based on the work they completed while at IRRI. Second, trainees were asked if they had been able to publish or present any papers based on research conducted since returning home. In the two-year period (1971-72) 130 former research trainees produced 370 technical papers. Since only 154 trainees indicated they were actively engaged in rice research and production programs when the survey was taken, and only another 5 percent of former trainees were working in other crop research programs, it was concluded that knowledge-generating research is predominant in the work of former IRRI research trainees. By contrast, it was found that of 105 active wheat research workers who were former CIMMYT trainees, 39 had published or presented a total of 101 technical papers during the same period.

IRRI Rice Production Training Program[24]

The IRRI rice production training program was established in 1964 in response to a growing need for competent rice extension specialists who could (1) diagnose serious rice problems, (2) grow a rice crop using the high-yielding rice technology that was being developed by IRRI, and (3) communicate these skills, methods, and techniques to rice producers through efficient

extension methods. Later, as it became apparent that IRRI could not begin to train all the rice production specialists needed by national programs, its focus was shifted to "training the trainers" of rice production specialists. The logic of this approach was to create a multiplier effect within each national program, whereby large numbers of field extension workers could be trained to use and demonstrate the new improved rice technology.

The rice production training program is a six-month course conducted during the wet-rice growing season beginning in early June each year. The behavioral objectives of the present program, in addition to the three original objectives as mentioned above, are (1) for trainees to be able to conduct applied research trials to modify the modern rice technology (package of practices) to fit local growing conditions in their home countries and/or regions and (2) to be able to organize and teach in-service rice production training programs for extension personnel in their home country programs.

To achieve these behavioral objectives, trainees spend about one-half of their time in the classroom learning up-to-date knowledge about modern rice production in the tropics and the other half in the field practicing this knowledge and acquiring new skills in rice production and in communicating this technical information. One of the most outstanding features of the training methodology is that the classroom instruction, which imparts extensive technical information about all aspects of modern rice production, is carefully organized around and integrated with the practical field training. What is learned in the classroom is directly relevant to the problems faced in the field. Second, the course is highly efficient in that it is completely organized before the trainees arrive (lectures, field practice, field trips, etc., are all scheduled), so that each hour is accounted for in terms of the instructor responsible and the behaviorial objectives to be achieved. In addition, most technical lectures, field practice exercises, etc., are reproduced and made available to trainees so that each has a rice production training manual and a complete set of technical lecture notes to use both during the training program and after returning home.

Results

Questionnaire responses show that nearly every former rice production trainee was satisfied with the overall training, and approximately 90 percent of the trainees indicated they were making some or full use of the training. The number of respondents who indicated they were in job assignments where they could make direct use of their training was less satisfactory. Although 81 percent of the respondents indicated that they were working in rice production programs, only about 42 percent were in positions directly associated with the stated behavioral objectives of the program.

In regard to the primary behavioral objective of the program, it was found that only nineteen respondents (12.8 percent) were assigned and working as full-time rice production trainers. Although two-thirds of the respondents indicated that they had worked, at one time or another, in organized rice production training programs, in most cases these duties were in addition to their regular job assignments. In addition to the nineteen respondents who are working as rice production trainers, it was found that another thirty-six respondents (24.3 percent) were working as rice extension specialists and eight trainees (5.4 percent) were involved with rice production programs, but as general agricultural extension workers. In all these cases trainees were considered to be directly involved in assignments associated with the behavioral objectives of the program.

Approximately one-fourth of the rice production trainees are research workers in their home countries. In fact, nearly 10 percent of former rice production trainees are currently working in rice breeding. How or why these trainees were selected for this program, rather than for the research training program in varietal improvement, was not established. Although rice production training is probably quite useful and appropriate for many rice research workers, their selection appears inconsistent with the stated objectives of the rice production training program.

The remaining trainees have moved into other types of jobs since returning home (many are in administrative positions), but some are still associated with rice production work. Eleven participants were attending a university when the survey was taken, and probably many of these will eventually return to rice production activities.

Effect of Different Training Strategies on Work Behavior

It was established in this study that the work behavior of the trainees in each of the three groups differed widely following their return to jobs at home. At the same time, however, there were great similarities in the general background of the trainees in the three groups. Therefore, the purpose of this section is to develop an adequate explanation for these differences in work behavior by examining the major independent and intervening variables.

No attempt is made to characterize one training program as better or worse than another; rather, the objective is to learn from the strengths and weaknesses of each training strategy. All training programs included in this study are generally well organized and have been evaluated favorably by former trainees. To establish this point, two major trainee-assessment variables are contrasted in Table 15-3.

There is no significant difference between the ways in which individual

Table 15-3. General Trainee Assessment of Each Training Program

Type of Training Assessment	CIMMYT Wheat Trainees	IRRI Research Trainees	IRRI Rice Production Trainees
Trainee's overall satisfaction with the training program			
Very satisfied	65.4%	55.6%	64.0%
Somewhat satisfied	32.3	35.5	34.7
Neutral or dissatisfied	2.3	8.9	1.3
Total	100.0	100.0	100.0
Trainee's use of training in his present job			
Full use of training	46.4	39.4	48.6
Some use of training	47.2	55.5	42.1
Little or no use of training	6.4	5.1	9.3
Total	100.0	100.0	100.0

trainees either perceive the use of their training or assess their training experience at each center. Therefore, from the viewpoint of the individual trainee, these programs have been equally effective in achieving specified training objectives.

As mentioned above, however, there is considerable difference among trainees in present job performance. Data on trainee work behavior are presented in Figures 15-1 and 15-2 for the three training groups, based on the subgroups of trainees who actually indicated direct involvement (when the survey was taken) in a wheat improvement or rice research and production program. The percentage of trainees indicating such direct involvement for each training group is as follows: CIMMYT wheat trainees, 83.3 percent (N = 105); IRRI research trainees, 71.3 percent (N = 154); and IRRI rice production trainees, 78.8 percent (N = 108).

It is clear from the data presented in Figures 15-1 and 15-2 that CIMMYT wheat trainees are completing more research activities associated with the development of biological technology than are IRRI research trainees. Although this difference in research emphasis was expected, the extent of these observed differences was not anticipated. An analysis of variance test was carried out between the CIMMYT and IRRI research training groups for each type of research activity. The differences in work behavior for the three technology development variables were statistically significant at the .01 level. Since these differences have an important influence on the type of national research capacity that develops, a detailed examination of the factors that contributed to these differences appeared warranted.

To account for these differences, an analysis was made using the concep-

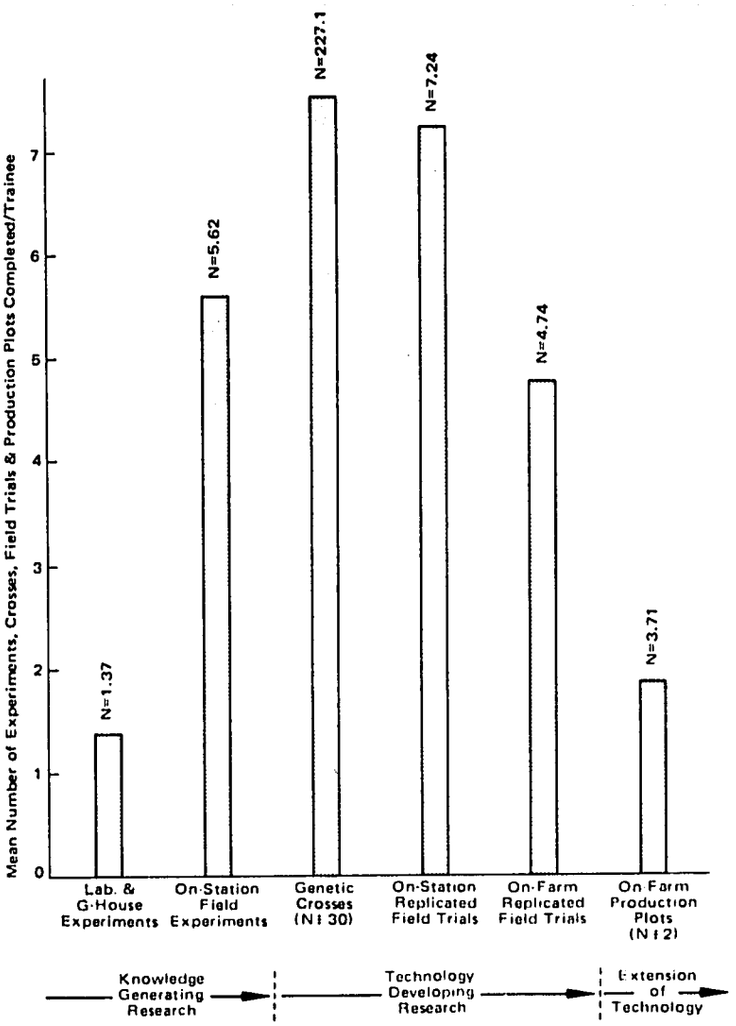

Figure 15-1. Work behavioral patterns of former CIMMYT wheat trainees.

tual model of the training process depicted in Figure 15-3. First, an examination was made of the two major independent variables: personal characteristics of individual trainees; and characteristics of trainees within their home organizations. Then, differences among trainees in respect to the main intervening variable – the actual training strategy and approach employed by each institute – were considered.

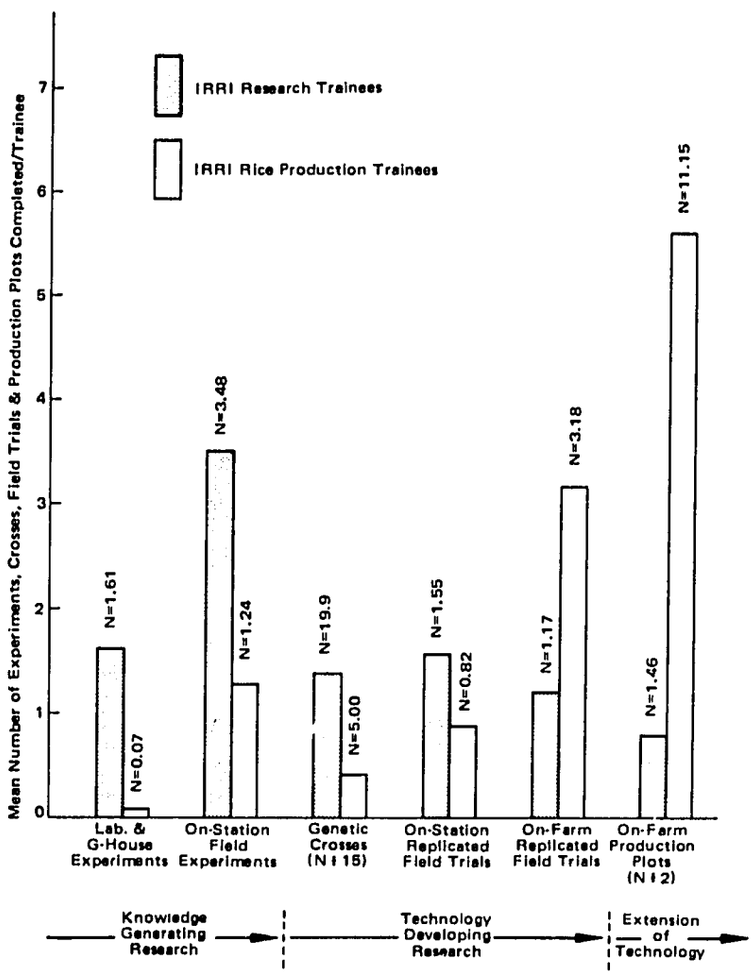

Figure 15-2. Work behavioral patterns of former IRRI research and production trainees.

It should be noted that the comparative analysis which follows concerns only the two research training groups. The work behavior of rice production trainees was included in Figure 15-2 because it provides a more complete profile of the research and extension activities being completed by former IRRI rice trainees, particularly since about one-fourth of former rice production trainees are engaged in research work. However, since this third group was trained to carry out essentially a technology dissemination role, it would be inappropriate to analyze this approach in terms of technology development.

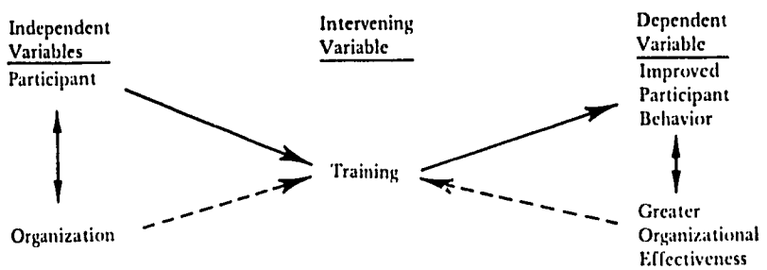

Figure 15-3. A model depicting the role of training in behavioral and organizational change.
Source: R. P. Lynton and Udai Pareek, *Training for Development* (Homewood, Ill.: Richard D. Irwin, and Dorsey Press, 1967), p. 18.

However, data on the two independent variables for the rice production group are included in the following section as a matter of information for the reader.

Personal Characteristics of Trainees

Several key variables describing the personal background and characteristics of trainees were tabulated to determine if there were any significant differences in the types of trainees that were being selected for each training program. In analyzing the data, several different multivariate linear regression models, using key independent variables, were developed in an attempt to predict different types and/or levels of work performance. None of the independent variables used in these analyses were found to have much influence (i.e., explain much variance) on the dependent variable. Table 15-4 summarizes data on these personal characteristics that might be expected to influence work behavior.

In terms of background characteristics, there are two apparent differences between the two research training groups which could affect work performance. The first, as documented in Table 15-4, is the difference in educational level between the two research groups. Although the IRRI research group is more highly educated – and this may influence somewhat the type of research conducted, which does appear to be the case – this factor would not be expected to have a negative influence on the overall amount of work completed.

The second major difference between the two research training groups is nationality and the possible influence of cultural factors on work behavior. The IRRI research group is primarily from countries in South, Southeast, and East Asia, whereas CIMMYT trainees are primarily from North Africa, the

Table 15-4. Personal Characteristics of Trainees in Each Training Group

Personal Characteristics of Trainees	CIMMYT Wheat Trainees (N = 130)	IRRI Research Trainees (N = 234)	IRRI Rice Production Trainees (N = 148)
		In Years	
Mean age when entering the training program	30.6	30.4	32.4
		In Percentage	
Trainees who grew up in rural areas	61.4	59.5	77.0
Trainees' fathers who were engaged in agricultural jobs	47.5	36.7	45.8
Trainees' families whose main source of income was from agricultural sources	47.7	43.2	55.5
Educational level of trainees when entering the training program			
Less than B.S. degree	21.1	1.8	22.4
B.S. degree or equivalent	57.8	62.3	65.0
M.S. or Ph.D. degree	21.1	35.9	12.6
Total	100.0	100.0	100.0
Present educational level of trainees			
Less than B.S. degree	20.5		17.5
B.S. degree or equivalent	41.7	16.2	56.6
M.S. degree or equivalent	27.6	41.2	19.6
Ph.D. degree	10.2	42.6	6.3
Total	100.0	100.0	100.0

Middle East, South Asia, and South America. Because there was insufficient overlap between the two groups to measure the impact of nationality or culture on work behavior, the importance of this influence remains unknown. However, nothing in my experience in agricultural training programs, where I have worked with a wide variety of cultural groups, suggests that cultural background would have a determining influence on the type and amount of work performed.

Characteristics of Trainees in Their Work Organizations

The next set of variables to be examined in attempting to explain differences in work behavior between the two research groups concerns the role of the trainee in his work organization when the survey was conducted. Table 15-5 presents data on certain selected variables that could be expected to influence the dependent variable.

There is no difference between research groups regarding the level of their

Table 15-5. Selected Variables Describing the Roles of Trainees in Their Work Organizations for All Three Training Groups

Characteristics of Trainees in Their Work Organizations[a]	CIMMYT Wheat Trainees (N = 130)	IRRI Research Trainees (N = 234)	IRRI Rice Production Trainees (N = 148)
Types of organizations where trainees are working			
National research organizations	88.0%	56.9%	20.0%
National extension organizations	6.4	1.9	47.9
Agricultural colleges or universities	2.4	27.3	12.1
Other	3.2	13.9	20.0
Total	100.0	100.0	100.0
Level of trainee's position in his work organization			
Policy level	4.0	4.7	2.9
Senior level	41.9	46.5	32.1
Middle level	50.1	45.0	54.0
Lower level	4.0	3.8	11.0
Total	100.0	100.0	100.0
Type of work trainee is engaged in			
Mainly administrative work	11.6	12.1	22.7
Mainly field research work	74.4	44.7	22.0
Mainly laboratory greenhouse research	6.6	24.1	3.8
Mainly field extension work	5.8	3.0	28.8
Mainly teaching or training	1.6	16.1	22.7
Total	100.0	100.0	100.0
Crops worked with by the trainee in his job assignment			
Works only with wheat/rice	71.4	40.7	32.8
Works with wheat/rice and other crops	19.9	31.5	48.2
Does not work with wheat/rice in his present job assignment	8.7	27.8	19.0
Total	100.0	100.0	100.0

[a] At the time the survey was taken.

present positions in their work organizations, but there are other important differences which could contribute directly to the observed differences in work behavior. First, there is a substantial difference in the relative proportions of trainees doing field research work. Since the work behavior of IRRI research trainees tends to emphasize experimental field research (as reported

in Table 15-2 and Figure 15-2), the fact that only about 45 percent of the IRRI research group (contrasted with nearly 75 percent for the CIMMYT group) are engaged in field research would be expected to have an important negative influence on the mean level of field research activities completed per trainee. Second, the important difference between the two groups in regard to crops worked with (71 percent of CIMMYT trainees worked full time on wheat research, whereas only 41 percent of IRRI research trainees worked full time on rice research) would also be expected to have some influence on the total amount of wheat/rice research completed.

These findings raise two obvious questions: Why are there such large differences between the two research training groups with respect to these two variables? And, what actual impact are these differences having on the amount of work completed by trainees?

Although there are no clear-cut answers to the first question, certain facts are known. First, IRRI selects trainees from educational as well as research institutions for its research training program. With 16 percent of former IRRI research trainees now working in full-time teaching positions within colleges of agriculture or universities, this group accounts for more than half the difference between the CIMMYT and IRRI research groups. Second, of those IRRI research trainees who are doing research work, more than one-third are engaged in laboratory/greenhouse research, and this group accounts for the remainder of the difference of those trainees doing field research.

Less easy to explain is the fact that only 41 percent of the research workers included in the IRRI research group are working full time on rice research, yet most come from countries totally dependent on rice as the major food staple. The only apparent reason is that the IRRI research group is trained in single-discipline departments and is more highly educated, which again would be an impetus to further disciplinary specialization. Once back home in their national programs, which are concerned with several different crops (rather than a single crop as is the case with IRRI), it is probable that these scientists will be called on to divide their research time among other crops in addition to rice. For example, a pathologist may be assigned to study fungus diseases of several crops rather than work on all different diseases of rice, such as bacterial blight, blast (a fungus disease), and tungro (a virus disease).

Trainees who have gone through the CIMMYT training program, which operates within an interdisciplinary research structure, have tended to continue their focus on wheat improvement rather than specialize on research problems within a particular scientific discipline.

The second question raised was, How much impact are these differences in trainee job assignments between the two research training groups having on the overall worl. of trainees? To address this question, the procedure was to

Table 15-6. Analysis of Variance of the Work Behavior of Individual Trainees Who Are Working Mainly on Field Research – CIMMYT and IRRI Research Training Groups[a]

Type of Activity Completed	CIMMYT Wheat Trainees (N = 79)	IRRI Research Trainees (N = 72)	t Values	Level of Significance
Laboratory and greenhouse experiments	1.76	0.61	1.1068	n.s.
On-station field research experiments	6.82	4.07	1.7757	n.s.
Genetic crosses	279.5	26.3	5.8646	**
On-station replicated applied research trials	8.95	2.00	4.3683	**
On-farm replicated applied research trials	4.95	1.68	2.4003	*
On-farm production plots	3.17	2.46	0.4226	n.s.

[a] Data reported are the mean level of each activity completed per trainee during the main wheat or rice growing season of 1972.

n.s. = not significant.

* = significant at .05 level.

** = significant at .01 level.

contrast the work behavior of two subgroups of trainees – those mainly doing field research work and those working only on wheat/rice research – with each of the two research training groups to determine if the observed differences in work behavior could be explained by either of these two independent variables or if the differences still persist. Results of these analyses are found in Tables 15-6 and 15-7.

As the data indicate, the observed differences in behavior for those research activities most closely associated with the development of improved genetic and production technology (rows 3, 4, and 5) continue to be present even when we consider just those subgroups of trainees that are doing mainly field research and those doing only wheat/rice research respectively. Therefore, it is concluded that, although a similar proportion of IRRI research trainees are working in field research work and a smaller proportion are only working full time on rice research, these differences in job assignments still do not explain the major differences in observed work behavior between the two research training groups.

To reiterate, it was not possible to account for the differences in work behavior between the two research groups by considering the two main independent variables: the differences in the personal background characteristics of the individual trainees in each group and the characteristics of trainee job assignments in their work organizations. These findings, therefore, direct the

Table 15-7. Analysis of Variance of the Work Behavior of Individual Trainees Who Are Working Only on Wheat/Rice Research – CIMMYT and IRRI Research Training Groups[a]

Type of Activity Completed	CIMMYT Wheat Trainees (N = 81)	IRRI Research Trainees (N = 82)	t Values	Level of Significance
Laboratory and greenhouse experiments	1.72	1.12	0.5778	n.s.
On-station field research experiments	5.89	3.84	1.3358	n.s.
Genetic crosses	261.2	28.0	5.5943	*
On-station replicated applied research trials	8.36	1.52	4.4190	*
On-farm replicated applied research trials	4.43	1.26	2.6425	*
On-farm production plots	3.77	1.99	1.1194	n.s.

[a] Data reported are the mean level of each activity completed per trainee during the main wheat or rice growing season of 1972.

n.s. = not significant.

* = significant at .01 level.

inquiry to the intervening variable – the training itself – to see if the differences in training could account for the observed differences in work behavior.

Differences in Training as an Intervening Variable

The training objectives, methodology, and strategy of the two research training programs being considered here are markedly different. Both training approaches were described earlier. The key points that appear to link these different training approaches directly to the differences in work behavior are as follows.

IRRI's main educational objective in its research project approach to training is analytical skill. In following this type of program the trainee learns firsthand how to design, carry out, and report on a research experiment and in doing so learns how to think analytically – a prerequisite for any successful research worker. Having this ability and skill, however, does not prepare a research worker for all types of research work. In particular, he does not learn the research skills and methods associated with organizing and operating a research program aimed at developing improved agricultural technology, where the primary educational objective is synthesis (an objective that characterizes the CIMMYT wheat training program).

The CIMMYT wheat research program is essentially a highly organized "genetic assembly line" which has standardized procedures and routinized tasks to increase the efficiency and output of a wheat improvement research

program, while minimizing error. By systematically and effectively mixing (synthesis) the gene pool through large numbers of genetic crosses and by systematically screening the progeny of these crosses, particularly through the extensive use of early generation testing procedures (evaluation), the biological architects at CIMMYT believe they can maximize the probability of producing superior germ plasm. CIMMYT wheat trainees appear to have learned and to have adopted this research approach to wheat improvement, given their observed behavior.

The conclusion of this study is that the different approaches to research training pursued by CIMMYT and IRRI are having an important and measurable influence on the work behavior of research workers in less developed countries. CIMMYT's training group tends to emphasize and to be very efficient and productive in conducting research aimed at developing improved wheat technology. IRRI research workers tend to emphasize experimental research aimed at generating new knowledge about rice production in the tropics.

Transforming National Research Capacity: A Postscript

As Ruttan and Hayami point out, one of the most serious constraints on the international transfer of agricultural technology is limited experiment station capacity for the production of biological technology.[25] The central theme of this chapter has been an analysis of the ways in which two international research centers have addressed this problem through their training programs. In making this analysis, however, it became increasingly clear that there was an issue involved more basic than just a difference in training objectives and methodologies. More important were the working assumptions made by each center concerning the ability of national research systems to organize their scientific resources. Although this is a complex issue, each center's response to this question provides some valuable insights into the problem.

CIMMYT's response to this question has been based essentially on the premise that the national wheat improvement programs with which it works have not been functioning effectively because they have been unable to organize their scientific resources to solve practical production problems. The problem is twofold.

First is the problem of focus, or research objectives. CIMMYT's response to this perceived institutional problem was to concentrate on one specific production problem – the need for improved genetic technology – and through its training strategy carefully and systematically to build this relatively simple research function into each national program. Thus organizational change was a specific, but implicit training objective.

Second is the problem of functional integration, or the ability of a national program effectively to organize and mobilize its scientific resources around the objective of producing biological technology. If we identify the lack of such ability as a serious institutional problem, it follows that technical personnel, in addition to lacking relevant research skills and methods, would also lack the skills and spirit of working together in organized, cooperative team efforts. More precisely, they would lack the organizational skills and perspective necessary to integrate their research functions around a specific research objective. Thus it was found that CIMMYT trainees in cereal technology spent one-fourth of their time in the wheat-breeding program, so that they would clearly understand and appreciate the functional relationship between their work in cereal technology and the work in the breeding program. Similarly, each training group spent a substantial amount of time working in each of the other research programs that are functionally involved in developing improved genetic technology.

Following the logic of this strategy, it was expected that, once a "critical mass" of trained research workers were present in a wheat improvement program, that program would function effectively. And it was expected that as this happened, each national program would (1) work out its own research structure (i.e., division of labor) to fit local needs and requirements and (2) take over the necessary informal on-the-job training of new personnel. Once this transformation had been achieved, CIMMYT expected national wheat improvement programs to be functionally competent to identify local production problems and meet long-term technological needs. My observations, made while pretesting the survey questionnaire in the field, suggest that this strategy is working.

IRRI's response to the problem of how national research programs organize their scientific resources has been based on a different policy decision. On one hand, IRRI officials and scientists have expressed serious concern that some national programs lack the ability to organize and direct their research resources toward solving local production problems. On the other hand, however, IRRI leaders have expressed a sensitivity and concern that their international activities not dominate the research capability of national programs.[26] By making an explicit policy decision against direct institutional intervention, IRRI placed itself in a position of taking, as a given, the ability of national programs to organize their scientific resources.[27] Furthermore, IRRI's research training strategy, while not resulting from this policy decision, is logically consistent with it.

IRRI is operating on the basis of the same type of institutional relationship that a college of agriculture (as an educational institution) would have with a functionally effective experiment station (as a work organization). The

college provides graduate students with a good theoretical background in a field of study, along with a solid research experience in designing, conducting, and reporting on a research project. Once hired by an experiment station for a particular research position, however, a student is given specific research responsibilities that he is expected to carry out, which are functionally integrated with the station's overall research program. Since it is unlikely that the student knows how to carry out these research responsibilities, he will generally be assigned to work closely with a senior scientist in the same program. After a season or two of this informal, on-the-job training, the inexperienced research worker will develop sufficient competence to function independently in carrying out his assigned tasks.

IRRI, by using the research project approach and by training research workers in separate single-discipline departments, does not address institutional problems, such as poorly defined or inappropriate research objectives and the lack of functional integration, through its training strategy. It should be noted, however, that several countries from which IRRI receives substantial numbers of trainees (for example, Japan, Taiwan, and Korea) are assumed to have rather effective research systems at the present time. Therefore, this type of research training may be quite appropriate in meeting their needs. Nevertheless, if these programs are in fact relatively strong and functioning effectively at the present time, there would appear to be little justification for IRRI to expend its scarce training resources on research personnel from these countries, when the important rice-growing countries of the tropics have weak research systems.

The observed work behavior of former IRRI research trainees, as they return home to concentrate on knowledge-generating types of research, raises obvious questions about IRRI's training strategy. Although trainees study production problems that are relevant to home country conditions, it appears that in most cases their research effort – as it contributes to the overall national research capacity – lacks sufficient emphasis on and attention to the problem of producing biological technology.

Conclusion

This chapter is built on the premise that as poor nations of the tropics and subtropics shift to modern agricultural production systems they will need effective research institutions to meet long-term technological needs. Experience suggests that, in some of these national research institutions, technology-development research activities are frequently neglected or are relegated to less qualified and/or less motivated research personnel, while more highly educated scientists concentrate on more theoretical research inquiries.[28] However, if national agricultural research systems are to be relevant and use-

ful to agricultural producers, then knowledge-generating research activities must be, to a large degree, directed by and integrated with the technology-developing research function. Furthermore, this technology-developing research system must be capable of effectively and efficiently transforming new knowledge into improved agricultural technology. Where the national research capacity for producing biological technology is weak or lacking, these national research systems will remain functionally impotent in their ability to solve serious production problems and nations will remain largely dependent on external agencies (particularly the international research centers themselves) for new sources of improved technology. An analysis of the observed work behavior of former IRRI and CIMMYT research trainees supports the proposition that different training approaches and institution-building strategies can have an important impact on the type of national research capacity that develops. Therefore, international centers must be fully cognizant of these potential influences on the technological capability of national research systems when designing their training and outreach programs.

NOTES

1. This chapter was written as part of a research project on international technology transfer systems, supported by the Program of Advanced Studies in Institution-Building and Technical Assistance Methodology (PASITAM) of the Midwest Universities Consortium for International Activities (MUCIA) through a 211(d) grant from the United States Agency for International Development. The original research on which this chapter is based was supported by grants from the International Rice Research Institute, the International Maize and Wheat Improvement Center, and the Land Tenure Center at the University of Wisconsin.

2. Vernon W. Ruttan and Yujiro Hayami, "Technology Transfer and Agricultural Development," *Technology and Culture*, 14:2, pt. 1 (April 1973), 124-125.

3. These international movements of wheat and rice varieties are well documented in Dana G. Dalrymple, *Imports and Plantings of High-Yielding Varieties of Wheat and Rice in the Less Developed Nations*, Foreign Economic Development Report no. 14, Foreign Economic Development Service (Washington, D.C.: USDA in cooperation with USAID, 1972).

4. CIMMYT and IRRI both made available exotic and elite germ plasm to cooperating national programs through this period, and to a differing degree these efforts continue.

5. See Committee on Institutional Cooperation, *Building Institutions to Serve Agriculture* (Lafayette, Indiana: Purdue University, 1968), p. 9; Willard W. Cochrane, *The World Food Problem* (New York: Thomas Y. Crowell, 1969), pp. 218-219; A. H. Moseman, *Building Agricultural Research Systems in the Developing Nations* (New York: Agricultural Development Council, Inc., 1970), pp. 29-30.

6. Derek J. de Solla Price, "The Structures of Publication in Science and Technology," *Factors in the Transfer of Technology*, eds. William S. Gruber and Donald G. Marquis (Cambridge: M.I.T. Press, 1969), pp. 94, 97.

7. See Sterling Wortman, "The Technological Basis for Intensified Agriculture," *Agricultural Development: Proceedings of a Conference Sponsored by the Rockefeller Foundation*, April 23-25, 1969, Bellagio, Italy (New York: Rockefeller Foundation, 1969), p. 31.

8. In terms of a research hierarchy, the *biological architect* is considered to be on at least the same intellectual level as any senior research scientist. In fact, although the biological architect may use less sophisticated research tools, the cognitive demands placed on these individuals are frequently more complex than those problems faced by scientists conducting analytical research. Unfortunately, however, the technology-developing function within the overall research process is generally considered (by the scientific community) to be in an inferior position to the knowledge-generating function. Therefore, less talented research technicians are frequently assigned to these technology-development roles, which may be one reason why many research programs, particularly in LDC's, have been so ineffective in producing improved agricultural technology.

9. Benjamin S. Bloom, ed., *Taxonomy of Educational Objectives, Handbook I: Cognitive Domain* (New York: David McKay, 1956), p. 144.

10. *Ibid.*, pp. 162-172.

11. *Ibid.*, p. 162.

12. See *ibid.*, pp. 185-192.

13. See Ruttan and Hayami, "Technology Transfer," pp. 141-143.

14. For example see, E. O. Heady, "Priorities in the Adoption of Improved Farm Technology," *Economic Development of Agriculture*, ed. E. O. Heady (Ames: Iowa State University Press, 1965), pp. 164-165; Hans W. Singer, "A New Approach to the Problems of the Dual Society in Developing Countries," *United Nations International Development Review*, 3:3 (1971), 24; Lester Brown, *Seeds of Change* (New York: Praeger, 1970), p. 52; C. P. McMeekan, "What Kind of Agricultural Research?" *Finance and Development*, 2:2 (1965), 73.

15. See Burton E. Swanson, "Training Agricultural Research and Extension Workers from Less Developed Countries," Ph.D. dissertation (Madison: University of Wisconsin, 1974), pp. 18-42, for a more detailed analysis of this problem.

16. See H. L. Wilcke and H. B. Sprague, "Agricultural Research and Development by the Private Sector of the United States," *Agricultural Science Review*, 5:3 (1967), 3.

17. Singer, "Dual Society," p. 24. Singer terms this condition "an internal brain drain."

18. The following section is a very brief summary of the training objectives and methodology being employed by the CIMMYT wheat program. For more detailed information on this training program and an evaluation of this strategy, see Swanson, "Training Agricultural Research and Extension Workers," pp. 101-187.

19. For a detailed description of this training methodology see Dugan H. Laird, *Training Methods for Skills Acquisition* (Madison: American Society for Training and Development, 1972), pp. 22-24.

20. See Swanson, "Training Agricultural Research and Extension Workers," pp. 117-123, for detailed information about and examples of how CIMMYT attempts to achieve its attitudinal objectives.

21. The data used in this chapter to analyze the performance of CIMMYT and IRRI trainees were based on an international survey of former participants conducted in 1973. Responses to mail questionnaires were obtained from more than 78 percent of the nearly 700 former trainees who had participated in one of the three training programs included

in this study. A detailed analysis of these follow-up data for each training group can be found in Swanson, "Training Agricultural Research and Extension Workers."

22. Laboratory, greenhouse, and field experiments are defined in this chapter as "knowledge-generating" types of research and genetic crosses and on-station and on-farm applied research trials are classified as "technology-developing" types of research. See Swanson, "Training Agricultural Research and Extension Workers," pp. 14-18.

23. This conclusion is based partly on the assumption that individual research experiments take more time to plan and execute than do applied research trials. The methodology of applied research trials can frequently be standardized and routinized to minimize time spent on planning, experimental design, and analysis.

24. The rice production training program is specifically designed for rice extension workers. The program is summarized briefly here, however, since one-fourth of its trainees were research workers.

25. Ruttan and Hayami, "Technology Transfer," p. 124.

26. See A. Colin McClung, "IRRI's Role in Institutional Cooperation in Asia," *Rice, Science and Man* (Los Baños: International Rice Research Institute, 1972), p. 38.

27. "The basic philosophy of these agreements was quite clear on an important point: they were in no sense intended to lead to the establishment of branch stations of the International Rice Research Institute. Rather, they were designed to foster improvements in the host countries' research and development programs. The degree and pace of IRRI's involvement *would be set by the decisions of local authorities* [emphasis added] and the work would be directed solely towards problems of concern to local rice scientists and rice farmers." McClung, "IRRI's Role," p. 28.

28. Moseman, "Building Agricultural Research Systems," p. 58; and Wortman, "Technological Basis for Intensified Agriculture," p. 21.