1986 Annual Report

International Maize and Wheat Improvement Center

Cimmyt
1966-1986

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Trustees in 1986

1 Ex-officio position, through June 1986.
2 Ex-officio position, beginning July 1986.

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Roberto Martínez L., Mexico, Head, Building Maintenance*

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Magni S. Bjarnason, Iceland, Breeder, Quality Protein Maize
James A. Deutsch, USA, Breeder, Advanced Unit
Dana Eaton, USA, Breeder, Advanced Unit
Gregory Edmeades, New Zealand, Physiologist
Brhane Gebrekidan, Ethiopia, Breeder
David C. Jewell, Australia, Breeder, Wide Crosses
James E. Lothrop, USA, Breeder, Highland Maize
John A. Mihm, USA, Entomologist
Hiep Ngoc Pham, USA, Breeder, International Testing
Bobby L. Renfro, USA, Pathologist
Margaret Smith, USA, Breeder, Backup Unit
Suketoshi Taba, Japan, Breeder, Germplasm Bank
Surinder K. Vasal, India, Breeder, Hybrid Maize
Willy L. Villena O., Bolivia, Training Officer

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Associate Scientists
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H. Renée Lafitte, USA

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Edwin B. Knapp, USA (based in Colombia)
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Pakistan
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Arnoldo Amaya C., Mexico, Head, Wheat Industrial Quality Laboratory
Girma Bekele, Ethiopia, Pathologist
Pedro Brajcich G., Mexico, Head, Durum Wheat Program
Peter A. Burnett, New Zealand, Pathologist
Gerbrand Kingma, The Netherlands, Head, Wheat Training**
A. Mujeeb Kazi, USA, Head, Wide Crosses Program
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J. Michael Prescott, USA, Head, Seed Health
Sanjaya Rajaram, India, Head, Bread Wheat Program
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Kenneth D. Sayre, USA, Agronomist
H. Ayla Sencer, Turkey, Head, Germplasm Bank
Ravi P. Singh, India, Pathologist/Breeder
George Varughese, India, Head, Triticale Program
Reynaldo L. Villareal, the Philippines, Training Officer

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Mahmood O. Osmanzai, Afghanistan**
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Robert Raab, USA
Tony B. Ramey, USA**
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Lesley A. Sitch, UK**
John Stapleton, Ireland**
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Patrick C. Wall, Ireland (based in Ecuador)

East Africa Region

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Enrique Torres, Colombia (based in Kenya)

North Africa and Iberian Peninsula

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South Asia Region

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Southeast Asia Region

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Southern Cone of South America

Man Mohan Kohli, India (based in Paraguay)

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James L. Longmire, Australia, Economist

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South Asia Region
Derek R. Byerlee, Australia (based in Pakistan)

Southeast Asia Region
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Michael P. Collinson, UK (based in Kenya)
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1 Acting Director of the Economics Program.
* Appointed during 1986.
** Left during 1986.

Management Review

Accomplishment and progress on many fronts characterized 1986 for CIMMYT. To mention but a few highlights: The Maize Program increased its commitment of resources to Africa with the creation of two additional positions in the eastern and southern regions. The Program made significant progress toward documenting maize germplasm bank accessions through a new computerized data management system. We also made rapid progress toward the goal of identifying heterotic patterns in CIMMYT maize germplasm, information that should prove useful in national hybrid development programs. And significant levels of insect resistance were made available to national programs through the newly organized Multiple Borer Resistance (MBR) maize pool.

CIMMYT's 20th anniversary symposium was but a prelude to a larger process of reorientation and renewal involving numerous staff representing all facets of the Center's professional life.

Many national programs continue to employ advanced CIMMYT bread wheat, durum, and triticale germplasm in their research programs. Of particular note has been the release of numerous varieties having CIMMYT germplasm in their backgrounds and the rapid increase in area devoted to Veery-based varieties. The Wheat Program initiated a new international research effort (based in Turkey) focusing on winter wheats and concluded an agreement with Poland that will expand our ability to effectively develop triticale.

In Economics a new Director was selected (Dr. Derek Byerlee, Australia) who will assume the position in 1987. Steps were taken to strengthen data analysis capabilities at headquarters with the addition of two associate staff, and a new on-farm research program in Malawi was initiated.

The year was significant in other ways as well. In September CIMMYT marked the beginning of its third decade. The occasion was celebrated with old and new friends alike in an atmosphere charged with appreciation for the past and anticipation of the future. Indeed, the inauguration of the newly completed Norman E. Borlaug Training, Conference, and Information Center was itself a rededication to the traditional values, the guiding principles of our organizational culture. The subsequent two days were devoted to an international symposium entitled Future of Maize and Wheat in the Third World; in-depth discussions were held among a group of key individuals from around the world who share a common interest in CIMMYT's future. A wide range of themes were touched upon during the symposium, from the more technical to the more inspirational, but all had in common a view toward new challenges on the Center's horizon.

The 20th anniversary, however, as well as an internal review of the maize program held last spring, were but a prelude to an even larger process of reorientation and renewal. It is this theme that will serve as the focus of the 1986 Management Review and one that will be revisited in years hence. It is given added significance in that during 1987 CIMMYT begins in earnest its strategic planning efforts. As currently envisioned, this will be an open and dynamic process drawing upon the talents and energies of numerous staff representing all facets of the Center's professional life. One end product of the process, of course, will be a long-term plan, but much more will be gained from the effort. The activity will be of a recurring nature, such that the Center can periodically reevaluate its medium-term plans in the light of changing opportunities and constraints.

Changes in the Board of Trustees

During 1986 several key changes occurred in CIMMYT's Board of Trustees:

Guy Vallaeys (France), a member of the Board since 1984, was elected Chairman, replacing Virgilio Barco who gave up many of his other commitments to assume the presidency of Colombia. Dr. Vallaeys, who specialized in tropical agriculture on the Faculty of Agronomy, Gembloux (Belgium), currently serves as Advisor to the Director General of France's International Center for Cooperation in Agricultural Development Research (CIRAD). Dr. Vallaeys and the rest of the Board, along with all CIMMYT staff, wish Dr. Barco the very best in meeting the challenges of Colombia's presidency.

H.K. Jain (India), a noted plant geneticist who has served on the Board since 1980, resigned in 1986 when he accepted an appointment as Deputy Director General for Research at the International Service for National Agricultural Research (ISNAR), The Hague, Netherlands. As a long-standing member of the Program Committee, Dr. Jain's thoughtful counsel and guidance proved invaluable to CIMMYT management.

Omond M. Solandt (Canada), distinguished research manager and consultant, took his leave of the Board after eight years of service. As Chairman of the Executive and Finance Committee, Dr. Solandt's efforts on CIMMYT's behalf were undertaken with the same energy and dedication that characterize his long career in science.

W.A.C. (Will) Matheison (England), longtime public servant and administrator, also left the board during 1986. Mr. Matheison served as Chairman of the Program Committee, participating in a number of in-house program reviews and preparing the 1982 External Program Review. Mr. Matheison's well-received contributions to CIMMYT always combined wisdom with wit.

Tomio Yoshida (Japan), left the Board in 1986 to join the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR). Dr. Yoshida, a soil microbiologist and Professor of Soil Science at the University of Tsukuba, will, through his efforts on the TAC, continue to make significant contributions to CIMMYT and, more broadly, to the CGIAR. We wish him well in those endeavors.

Peter R. Day (United Kingdom), Director of the Plant Breeding Institute (PBI), Cambridge, joined the Board in the fall of 1986. Dr. Day's career in agricultural science spans two continents: educated in the United Kingdom, he served from 1964 to 1979 as Chief of the Genetics Department, Connecticut Agricultural Experiment Station (New Haven, Connecticut, USA), moving from there to his current position with PBI. Along the way, he received a number of awards and fellowships, including the Guggenheim Memorial Fellowship (University of Queensland) and the American Phytopathological Society Fellowship.

Zhuang Qiao-sheng (left) and Stachys Muturi, members of the Program Committee of CIMMYT's Board of Trustees. During 1986 the Committee began a comprehensive review of the Center's crop programs in preparation for the strategic planning effort to be initiated in 1987.

Ahmed A. Goueli (Egypt), former Professor and Chairman of the Department of Agricultural Economics, Zagazig University and now Governor of Damiett Province, came to the Board last year as well. Dr. Goueli received his Ph.D. in agricultural economics from the University of California, Berkeley (USA), after which he joined the Egyptian Ministry of Industries as an Economic Expert. From 1966 to 1971, he served as an Assistant Professor of Agricultural Economics on the Faculty of Agriculture, University of Ain Shams, and then assumed his position at Zagazig University. Dr. Goueli has served on a number of noted national and international committees, and has worked as a consultant dealing with a range of agricultural issues for the Food and Agriculture Organization (FAO), United Nations Development Programme (UNDP), and Ford Foundation.

Hikoyuki Yamaguchi (Japan), Professor of Radiation Genetics at the University of Tokyo, also joined the Board in 1986. Dr. Yamaguchi has extensive research and teaching experience in genetics and plant breeding, and brings to the Board a special perspective on the application of new science to our more traditional disciplines. He spent nearly 12 years on research activities related to the International Atomic Energy Agency and in the late 1970s served as Director of the Research Center for Nuclear Science and Technology at the University of Tokyo.

Financial Summary

CIMMYT's total revenues increased by $2,217,000 or 7 percent from 1985 to 1986 The largest portion of this increase was in grants, particularly those from extra-core donors. This is a reflection of increased activities in selected regional and national programs funded by these donors, and the completion of the Norman E. Borlaug Building, which was funded as an extra-core project by the Government of Japan and the Japanese Shipbuilding Industry Foundation (see page 47). Revenue from CGIAR donors to the Center's core program increased by only 4 percent, reflecting the diminishing growth of the core program. One new member of the CGIAR, the government of Austria, contributed to our core program. We recognize that these core donors represent the backbone of CIMMYT's research and training programs, and we are continually seeking to strengthen our relationships with them.

Inflation and exchange rates continued to play an important role in the Center's management. Their eventual values played an important role in determining annual revenues, wage adjustments, and major expenses for the renovation and maintenance of the physical plant. In general, the weakness of the dollar resulted in higher dollar revenues from donations denominated in other currencies. Unfortunately, the timing of some payments resulted in smaller gains than hoped. Still, CIMMYT did benefit from the shift in the value of the dollar. In Mexico itself, where inflation was over 100 percent, the devaluation of the peso permitted the investment of somewhat more funds in our research and training programs.

CIMMYT's externally audited financial statement is presented later in this report (pages 69-82). It shows the Center's financial condition at year end and the effects of financial flows during the year. Most pleasing is the significant increase in the value of property, plant, and equipment. This reflects the completion of the Borlaug Building and the remodeling of portions of the main building. Both these moves gave the Center much greater capacity for handling staff, visitors, and trainees, and permitted the installation of new electronic data processing networks and graphic design facilities. All these will add greater efficiency and effectiveness to our operations. Less promising was a markedly reduced interest income during the year. Most CIMMYT funds are now received in the latter half of the year and a relatively large portion of these in the final three months. Not only does this make cash management difficult, but it also reduces interest income. Over the last three years income from these investments was two to three times as high as for 1986, the difference being a consequence of lower interest rates and later payments by donors. In 1987 we will focus more attention on cash management and work with donors to find a more favorable solution to this problem.

The 1986 financial statement follows the recently adopted CGIAR accounting guidelines and reporting formats. We hope this gives a clear and concise view of CIMMYT's finances. One noteworthy new item is the capital development fund, which we intend to use as a basis for the medium- and long-term assessment of capital and maintenance needs. This will give a financial foundation for planning equipment needs and undertaking preventive maintenance, and will help to forecast future cash requirements. As the Center's physical plant grows older and the equipment and facilities required to undertake agricultural research become more sophisticated and costly, the prudent management of capital development funds will be ever more vital for the Center and for the CGIAR.

Observations on Strategic Planning

As noted at the beginning of this report, CIMMYT launched its strategic planning process in 1986 with an internal review of the Maize Program; the 20th anniversary celebration and symposium were organized with that objective in mind as well. Directing staff and others also began the task of identifying the critical dimensions of the planning process. These events, combined with an internal review of the Wheat Program in the spring of 1987, will serve to underpin much of the analysis that will occur in the months ahead.

Strategic planning is a complex process, involving a comprehensive analysis of the major facets of an organization. These various facets are themselves complex and nearly always highly interrelated, adding to the difficulty of the task. By virtue of the activities required, strategic planning is at once introspective and outward looking. It is introspective to the extent that detailed assessments are made of key managerial, scientific, and support program components. The process is outward looking to the extent that much energy is devoted to understanding and anticipating changes in the broad environment within which the organization must operate, with particular emphasis on the future needs of clients and alternative ways to satisfy those needs.

CIMMYT's future operating environment is made up of a number of key elements. The framework created by the CGIAR and TAC helps to delineate our perceptions of research opportunities and constraints. Among such considerations are the CGIAR's recent reaffirmation of the system's focus on foodstuffs and low income groups, along with the relative priorities given by the TAC to various commodities, the importance of assessing the environmental impacts of new technologies, of sustaining yields, of engaging in more strategic research at the Centers, and of the attendant devolution of certain Center activities to advanced national programs.

Beyond that, we give heavy emphasis to evaluating the future needs of our clients, which will serve to orient much of what we will be doing in the next decades and how we will be doing it; in this context, we must also assess the potential of various other suppliers to meet our clients' needs. Long-term trends in the production, consumption, and trade of maize and wheat also figure prominently in the evaluation, as do changes in science, with their implications for our work and that of others.

Strategic planning is at once an introspective and outward-looking process that gives particular emphasis to anticipating the future needs of clients.

In the light of this environmental assessment, then, we will go on to determine more clearly the mission of the Center, which enterprises we should be involved in, what the product mix and the relative priorities given to each should be, and which strategies are needed to achieve desired results. All of this will then be compared to a current profile of the Center and its strategies and activities, with an eye to determining whether and how that profile needs to change in order to remain viable in the future. At this point, too, financial and budgetary considerations come into play in determining the feasibility of proposed changes.

External participation in our efforts will characterize CIMMYT's strategic planning endeavors. The thinking of representatives from national agricultural research programs will be actively solicited, the Center's Board of Trustees will be mobilized to participate, and various outside consultants who are noted for their vision will be invited to share their perspectives. These contributions will be added to those of staff from all levels within the Center, giving a well-rounded thoroughness to the process and its eventual results.

Although it is premature to comment in detail on probable outcomes of the process, a few observations can be made as to the major areas that will receive attention; within each of them, a number of strategic issues will be reviewed. Those questions arise at this juncture in CIMMYT's evolution as a natural consequence of contemplating the future. They represent the kinds of issues that must be explicitly considered on a periodic basis to maintain the long-term health and viability of the Center. Only by asking ourselves and others the difficult questions exemplified by those noted below can we hope to continue meeting the changing needs of our clients.

We are organizing the strategic planning process around six major categories: training, collaboration with national agricultural research programs, germplasm products, basic and strategic research, crop management, and information. Clearly, there is a high degree of interdependence among these categories as well as a number of strategic issues contained within them. Finance is not considered as a separate category, but rather as integral to each of the six.

Training—The Norman E. Borlaug Building is perhaps the most visible manifestation of the Center's commitment to quality training of national program staff, and we anticipate that the coming year's deliberations will give it a continuing high place. Even so, there are a host of important questions to review. Among them are such issues as general versus more specialized training, the effectiveness of in-country versus headquarters-based training, and the role of training materials in extending the reach of our efforts.

Collaboration with national programs—At this point in CIMMYT's development, it is essential that we gain a clearer sense of how the needs of our clients are evolving and how we might better respond to those needs. Our current activities in this area cut across the range of more traditional modes of cooperation, from headquarters-based relations to regional and bilateral programs. The question needs to be raised as to which among these are proving most effective in light of our mandate and

Miguel de la Madrid Hurtado (right), President of Mexico, was in attendance at the 20th anniversary celebrations to formally inaugurate the Norman E. Borlaug Building.

whether relative priorities should be adjusted. In a broader context, we need to evaluate how we are assigning our resources among competing demands. New forms of collaboration are also in the offing, such as innovative types of networking, and we need to thoroughly evaluate their potential.

Germplasm products—A number of interesting questions confront us here, and it is likely that more will surface in the course of discussions. Among them are the role of agroecological zone delineation (to indicate what we refer to as *mega-environments*) in priority setting and orienting germplasm development efforts, general versus specialized germplasm, broad versus narrow adaptation, the extent to which we decentralize our breeding activities, and the amount of resources we should be allocating to genetic conservation.

Basic and strategic research—Here, too, there is no shortage of challenges. Key considerations include the relative need for basic and strategic versus applied and adaptive research, and the implications for national programs of the balance among them, factor versus disciplinary research, networking in research, the long-term environmental impacts of the technological components available to national programs, and the implications for income of technological change.

Crop management—Issues of strategic importance in this area continue to excite interest within CIMMYT. They include such considerations as yield sustainability and environmental impact, crop management in stress environments, the effectiveness of and requirements for crop rotations and intercropping techniques, and the relative roles of on-station and on-farm research.

Information—Rapid changes in information technologies have opened new areas for consideration within the Center. These relate to, for example, the role of information for internal and external use, to cost-effectiveness in satisfying demands, to the potential for inter-institutional cooperation, and to the roles of data processing and statistical support services.

Conclusion

Much of CIMMYT's energies during the coming year will be given over to the development of a strategic plan. The 20th anniversary symposium and its attendant activities were really only the first blush of a comprehensive evaluation and planning process. Although the energies required by such an endeavor are notably high, the potential payoffs easily justify the investment. The Center's management and staff look forward to the challenge of carefully preparing for our own future, secure in the belief that CIMMYT will be an even more effective organization, that national programs will benefit from our efficiencies, and that ultimately the farmers and consumers of developing countries will gain ground toward a better life.

Guy Vallaeys
Chairman, Board of Trustees

Donald L. Winkelmann
Director General

A Review of CIMMYT Programs

Maize physiologist Gregory Edmeades taking soil samples in an evaluation of materials selected for drought tolerance.

The basic task of every CIMMYT scientist is to identify problems and needs in agricultural research for the Third World and to seek effective ways of dealing with them. This search for practical means toward useful ends implies much individual effort but also a large degree of reliance on and accountability to others. Usually, the research tasks are complicated enough that they require a multidisciplinary approach and often call for the joint participation of numerous groups. Seldom is the judgment of any single group an adequate basis for assuming that the most urgent problems are being addressed or that they are being dealt with in a cost-effective manner. A much better guarantee that the research is well-targeted and efficiently managed is to maintain strong ties and open channels of communication with various peer groups whose opinions have some bearing on research priorities and plans.

Thorough accountability to our peers in the agricultural development and scientific community is especially important in view of the Center's mission, which requires prudent and efficient use of donors' funds in the service of maize, wheat, triticale, and economics research conducted by scientists in the Third World. The weight of this responsibility is increased by the considerable autonomy of the Center within the CGIAR system, which makes it incumbent on CIMMYT to have a reliable mechanism for establishing priorities and enough flexibility to adjust them according to changing needs and circumstances in the research programs of developing countries. Fulfilling that obligation is a vital part of our trust to a large and diverse public that includes hundreds of researchers around the world, the farmers they serve, and the donors who wish to assist them.

During 1986 various groups examined the research and training programs of the Center to consider how its staff should be discharging their public trust in the coming years. Some of the observers, including most participants in the 20th anniversary symposium, were developing country representatives and other experts from outside CIMMYT. They were particularly helpful in calling attention to issues, such as the application of biotechnology to crop improvement, that will be central in the strategic planning process initiated this year. Much of the scrutinizing, though, was done by Center scientists themselves and by the Board of Trustees. In March, for example, the Program Committee of the Board met at our headquarters in Mexico for a comprehensive review of maize germplasm development work. A similar review of the Wheat Program will take place early in 1987. In addition, just prior to and after our 20th anniversary celebrations, the Maize, Wheat, and Economics Programs held a series of staff meetings to consider current research priorities and approaches.

Having a reliable mechanism for establishing priorities and enough flexibility to adjust them according to client needs is a vital part of CIMMYT's public trust.

Research Products and Services

The center of attention during those events was CIMMYT's products and services and its vehicles for delivering them. The former are of five main types:

- Improved germplasm for major production environments in the Third World, particularly the less favored ones
- Efficient procedures for plant breeding, crop management research, and agricultural decision making
- Training for agricultural scientists in developing countries
- Technical consultation and assistance for national agricultural research programs
- Scientific information provided in the form of publications, collections of abstracts, and on-line data base searches

Those products and services are provided by about 80 scientists and other specialists working in the three main programs—Maize, Wheat, and Economics—and in various support units. Roughly half of the scientific staff are based in Mexico and the rest in regional programs or bilateral projects throughout the Third World.

The Work at CIMMYT Headquarters

Most of the researchers at headquarters are developing and improving germplasm. This work is carried out, with assistance from laboratory and experiment station units, at five principal locations in Mexico, which represent different types of production environments commonly found in developing countries. Products of the germplasm programs are distributed to hundreds of locations around the world through maize, wheat, and triticale testing networks.

For most of the last 20 years, CIMMYT has not been the type of centralized organization implied by the term center. Since the early 1970s, about half of our staff have gone into outreach programs that touch nearly all regions of the Third World.

Each of those products is designed for a particular *mega-environment*, which is a subdivision of one of the major agroecologies found in the Third World (lowland tropics, subtropics, and so forth). These subdivisions are distinguished from one another by differences in availability of moisture during the growing season, incidence of various diseases and insect pests, soil types, and other conditions that determine the characteristics farmers must have in improved maize, wheat, or triticale. The areas that make up each mega-environment are not necessarily contiguous, or even on the same continent, but are roughly uniform in their germplasm requirements.

The relative uniformity of mega-environments across continents has tremendous implications for global germplasm development. One can be reasonably certain that a maize variety, for example, which performs well at a Central American location representing a particular lowland tropical mega-environment will respond similarly at an African location possessing the essential features of that same mega-environment. This ability to transfer results obtained on one continent to corresponding locations on another enables CIMMYT to work at a few representative sites in developing maize, wheat, and triticale germplasm for most regions of the world. Because our varieties and other materials are targetted for broad mega-environments, they are by definition intermediate in nature and must often undergo further refinement by plant breeders in the Third World before they can be considered final products ready for release to farmers. We view this process of refinement as an indispensable element in the development of national crop programs, one that contributes substantially to their research capacity and self-sufficiency and which, in any case, is quite properly their responsibility.

Those programs vary greatly, however, in their level of development and require various forms of assistance in their breeding and other work. Our staff at headquarters, for example, are heavily involved in training programs aimed at improving the research capacity of their colleagues in developing countries. Those staff also devote a considerable portion of their time to generating technical information, most of which is prepared and distributed by the Information Services Unit. Conferences and workshops held at headquarters provide another forum for the exchange of research ideas and results. In all of those activities, scientists and other specialists are ably assisted by a support staff in Mexico of about 850 people.

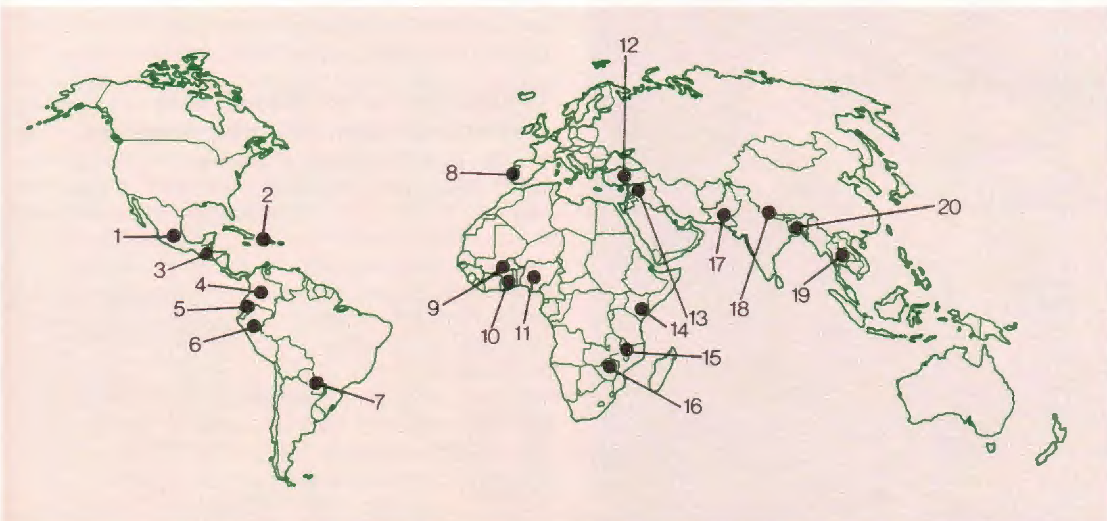
Regional Programs and Bilateral Projects

The various units at headquarters make up the core of the Center's research and assistance program, and in the eyes of some people they are CIMMYT. But for most of the last 20 years, we have not been the type of centralized organization that is perhaps implied by the term *center*. Since the early 1970s, about half of the scientific staff have moved into bilateral projects or set up maize, wheat, and economics regional programs that touch nearly all regions of the Third World. Those programs have proved to be extremely versatile and useful, performing a number of functions that could not be done at headquarters.

One of their functions is to offer counsel and assistance in the use of germplasm and other products available from CIMMYT headquarters. As suggested previously, many of those products are somewhat like partially finished items from a workshop in that they often require additional refinement before being released to farmers. The complicating factor is that no two Center clients will employ our products in exactly the same way or under the same circumstances. For that reason the regional specialists provide highly individualized assistance primarily through timely visits to research programs in the various regions.

From their visits to experiment stations and farmers' fields, the regional specialists come away with a clear sense of the needs of research programs in developing countries. That information is conveyed to Center headquarters, where it is taken into account in decisions about the research programs. During recent years the information link between headquarters and national programs via the regional networks has proved to be an essential aid in setting priorities and allocating research resources. Because we have had more accurate and abundant information about germplasm and other needs in the Third World, we have been better able to identify and concentrate on truly urgent problems, adjusting our resource allocations accordingly. This information is also helping us explain to donors, scientists, and others who have an interest in the Center's work why we are employing our human and financial resources in particular ways.

The brief reports that follow show what we are learning about the requirements of crop research in developing countries and about efficient ways of meeting them. More detailed accounts of the Center's activities are given in the *CIMMYT Research Highlights* series and in other recent publications.



Locations at which CIMMYT staff are based.

Maize Research

During 1986 important steps were taken by various units of the Maize Program to sharpen the focus of our research on particular germplasm needs in the Third World. (See box for an overview of the various groups that make up the Maize Program.) Those steps were of two main types. The first included actions taken by several units working on stress tolerances or resistances, traits that should help remove some of the uncertainty of developing country maize production by ensuring more stable yields from year to year. The second type consisted of adjustments made by various groups in the Program that are developing and improving special categories of germplasm. These materials differ from other types of maize germplasm in two ways: some have special traits, while others can best be handled at locations away from headquarters. These circumstances have led us to set up several highly specialized breeding programs that operate somewhat independently, but with definite links to, our mainstream germplasm program.

This year's work on stress tolerance breeding and on special categories of germplasm is described in the first two sections of this report on maize research. We then briefly review the activities of our training and regional programs.

As mentioned in the *1985 Annual Report*, scientists in regional posts have been working with staff of our international maize testing program to gather information on germplasm needs in the Third World's major production environments. We have almost completed the task of collecting data and have begun organizing and analyzing it. Already this information has proved to be quite useful as a guide to our stress tolerance work, development of special categories of germplasm, and other maize breeding activities.

Directions in the Mainstream Germplasm Improvement Program

When the Maize Program initiated its work 20 years ago, improved maize germplasm for the lowland tropics and other agroecologies found in the Third World was quite scarce, and relatively little was known about germplasm needs and appropriate ways of meeting them. Since then the Program has made considerable headway in creating a wide range of improved materials for most of the principal maize mega-environments, and developing countries have steadily improved their capacity to further refine such materials for use by farmers. In the process, particularly during recent years, national scientists and CIMMYT staff have gathered a sizeable body of knowledge about maize germplasm requirements in developing countries. Based largely on that information, the Program has begun to bring more of its resources to bear on improvement of specific traits (mainly stress tolerances) that are needed for Third World maize production. Wider availability of materials carrying those traits will put fairly advanced maize programs in a better position to adapt elite germplasm more completely to farmers' requirements.

Regional maize specialist Carlos de León (center) consulting with national staff at a trial site in Kampuchea.

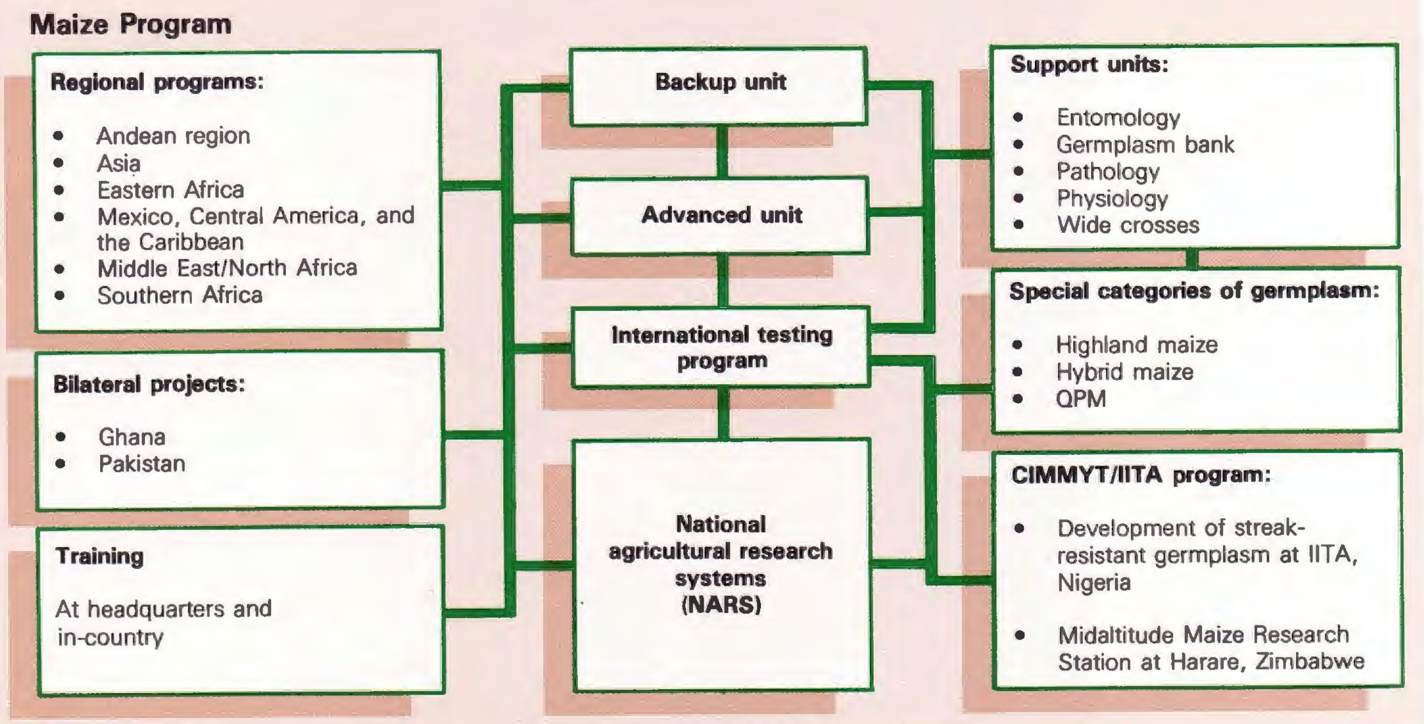
Activities and Structure of the Maize Program

Maize research and training are conducted by a multidisciplinary team of 17 scientists at CIMMYT headquarters and by 14 maize specialists in six regional programs (see the diagram). In addition, three scientists are working in the national maize research programs of Ghana and Pakistan, and four are engaged in maize breeding projects in Africa that operate as remote units of the maize improvement program at headquarters.

The mainstream of our breeding program consists of the backup and advanced units and the international testing program. The backup unit is responsible for germplasm complexes that we refer to as *pools*, while the advanced unit handles more highly refined *advanced populations*. The plant breeders that staff those units work closely with the entomology, pathology, physiology, germplasm bank, and wide cross units, which provide new sources of resistance and tolerance to various stresses or try to raise the levels of these traits in elite germplasm. Superior materials (full-sib families and experimental varieties) are distributed to researchers in national agricultural research systems (NARS) through the international maize testing program.

Other units in the program are developing and improving the following special categories of germplasm: highland maize, hybrids, and quality protein maize (QPM). Those groups, like the ones comprising the mainstream breeding program, are aided by entomologists, pathologists, and other specialists, and the distribution and testing of their germplasm products are coordinated by the international testing program. Another special category of germplasm (midaltitude maize) as well as streak virus resistant materials are being developed in a cooperative program with the International Institute of Tropical Agriculture (IITA).

Scientists in NARS receive assistance in the use of intermediate germplasm products and in related work (such as agronomy and seed production) from maize specialists in regional programs and bilateral projects. Those staff also help identify training needs, some of which are met by in-service courses and visiting scientist fellowships at headquarters. When special training needs arise, outreach staff organize courses and workshops that are tailored to the requirements of maize programs within their regions.



Gene pools—Much of the responsibility for developing readily usable sources of certain traits will reside with the backup unit.

The gene pools formed by that unit in the past were broad-based materials representing most of the maize types grown in developing countries and possessing reasonably good agronomic quality and field tolerance to a number of stresses. In the coming years, new materials fitting that description (which we refer to as *general-purpose pools*) will be developed by the backup unit from the best germplasm available for specific areas. With those pools we hope to satisfy the need for a continuous flow of raw materials that can be used by developing country breeders in population improvement and variety selection.

An increased portion of the Backup Unit's efforts is being devoted to special-purpose pools, agronomically acceptable materials into which we are incorporating genes for stress tolerances.

A greater portion of the unit's efforts, however, is now being devoted to another category of germplasm complexes that we term *special-purpose pools*. These are agronomically acceptable materials into which we are incorporating genes for tolerances to one or a few biotic or abiotic stresses, such as stalk borers and drought. Our work with those materials represents quite a departure from previous stress-tolerance breeding in the pools. Selection for resistance to fall armyworm, for example, used to be conducted simultaneously with selection for many other traits. Since all of them were emphasized equally, progress in some, such as fall armyworm resistance, was extremely slow. We expect to make more rapid progress by assembling all the materials we can find that have shown resistance to a given stress and in the pool so formed to select intensively for this trait.

Selection for most traits (particularly those requiring laboratory support or precise environmental control) will be conducted at CIMMYT headquarters, assuming that the appropriate selection environment can be found or created there. If conditions are not right for selection in Mexico, it will have to be carried out elsewhere under cooperative arrangements with other institutions. In any case, because of the complex nature of many of the traits that are needed, selection in the special-purpose pools will inevitably be a long-term endeavor, but one that within a reasonable time will provide breeders with valuable sources of stress tolerance.

Several steps toward that objective were taken this year, including important decisions as to what traits are needed for particular mega-environments in the Third World. In addition, work was initiated with a drought-tolerant pool and with materials showing resistance to stalk borers. Much of this early work is intended to identify and group sources of resistance for more convenient handling. In that and other current and projected activities, the Backup Unit will require close cooperation with virtually every other unit in the Maize Program as well as with our regional staff and colleagues in national programs.

Insect resistances—Entomology is one unit that is already well along in the development of special-purpose pools. This work was begun in 1984 with the formation of a multiple-borer resistance pool (MBR) from seed of all maize that had been reported to be resistant or was being selected for resistance to borer species that attack the crop. In subsequent evaluations the pool showed sufficient resistance to the southwestern corn borer, sugarcane borer, and fall armyworm that by 1986 it was ready for international testing to determine its potential usefulness in other countries and to obtain data that would assist us in further improving the pool and in developing new products from it.

Superior families from the pool were distributed for testing at 10 sites in six countries (Kenya, Mexico, Nigeria, South Africa, Turkey, and the USA) where facilities are available for mass rearing of and artificial infestation with various borer species. Although not all the test results are in yet, it appears from the data we have that a significant number of families are showing at least intermediate resistance to five borer species. We can be fairly confident, therefore, that selecting for resistance to the borer species prevalent in Mexico gives us a good chance of obtaining germplasm with resistance to species found in Africa and Asia.

Even so, the MBR pool, like any other maize germplasm, is limited in its range of adaptation. Being a subtropical material, it will probably never be able to supply the disease resistance and agronomic characters needed in maize germplasm for the lowland tropics, even though its progeny possess resistance to tropical borer species. For that reason the entomology unit has developed another resistance source, the multiple-insect resistant tropical pool (MIRT), which contains some of the same materials included in the MBR pool but is composed largely of insect-resistant selections from the Maize Program's tropical germplasm. Already the MIRT pool is showing good resistance to the sugarcane borer and fall armyworm and by 1988 should be ready for international testing in the lowland tropics.

Tolerance to abiotic stresses—A large part of the instability of maize production in the highly uncertain marginal areas of the Third World is accounted for by harsh physical conditions. Any program therefore that aims to improve yield stability in marginal environments must come to grips with those stresses, in addition to developing insect- and disease-resistant germplasm. Developing tolerance to abiotic stresses is a primary responsibility of the Maize Program's physiology unit, which has come to focus on two major problems, drought and low availability of nitrogen. The choice of those problems, like the selection of priorities in the backup unit, was based on information we have gathered about the conditions of maize production and on the experience of our maize scientists in developing countries.

In its work on drought tolerance, the physiology unit is currently pursuing a dual strategy that consists of a short-term and a long-term approach. The former involves a modified version of the recurrent selection procedure employed in the population Tuxpeño Drought during the 1970s. Selection is now being conducted in four elite materials that are commonly used by maize breeders in drought-prone regions. During 1986 those materials were evaluated at the Program's station in Tlaltizapan. Two of them had been evaluated during the previous season at other locations, Pool 18 in the hot, dry environment of Ciudad Obregon, Mexico, and Pool 16 in Burkina Faso.

Plant breeder Margaret Smith selects ears in materials handled by the backup unit, which is responsible for providing maize breeders with readily usable sources of stress tolerances.

The aim of this two-stage, two-location selection and testing procedure is to provide breeders in developing countries fairly soon with elite germplasm showing reasonably good drought tolerance.

The long-term approach, begun this year, is to develop a pool characterized by unique drought tolerance. The main building block of this pool is cycle 8 of selection in Tuxpeño Drought; it also contains materials from the US Corn Belt, drought-resistant Mexican landraces, and a hybrid derived from Thailand's Suwan 1 germplasm. Other germplasm possessing drought tolerance characteristics will be added as it is identified. At present the pool is less agronomically desirable than elite germplasm, but we expect that over time it can be made into a more readily usable source of drought tolerance.

Several valuable contributions of the physiology unit in its work on drought have been to assemble sources of tolerance, find new selection techniques and criteria, and demonstrate that progress can be made through recurrent selection.

Several valuable contributions of the physiology unit so far in its work on drought have been to assemble sources of tolerance, find new selection techniques and criteria, and demonstrate that progress can be made through recurrent selection. The unit is accomplishing essentially the same objectives in its efforts to improve nitrogen-use efficiency in maize grown under low nitrogen supply. This is a much-needed trait in the many developing countries where nitrogen fertilizer is not widely available to farmers.

A program of recurrent selection for improved performance under low nitrogen levels was initiated this year and a trial of 16 elite materials and two landraces conducted to identify useful selection criteria. It appears from the results of that trial that several traits are correlated with grain yield at low levels of nitrogen. One of those, leaf chlorophyll content (which is an indirect measure of nitrogen status in the leaves) should be particularly useful, since it can be gauged rapidly in the field with a portable photometer. Using that and other criteria, we will continue selecting under different nitrogen levels in promising materials such as the variety Across 8328, which has performed well across nitrogen levels.

Disease resistances—With some notable exceptions, these traits have proved to be less elusive than insect resistances and tolerance to abiotic stresses, and for some time the Maize Program has had in place several effective strategies for developing disease resistances. One of them is selection for multiple resistance, often under artificially created disease pressure, at experiment stations in Mexico. That approach has led to reasonably good protection against ear and stalk rots and leaf blights and rusts in a range of pools and populations, which are being channeled through the advanced unit and international testing program to researchers in developing countries.

For the several important diseases that do not occur in Mexico, we have set up various cooperative arrangements with institutions in other countries. Breeders in Thailand's maize program, for example, this year completed their fourth cycle of recurrent selection for downy mildew resistance under the direction of our regional program in Asia. At IITA in Nigeria, a CIMMYT maize breeder continued to incorporate maize streak resistance into superior experimental varieties and to improve Population 43 and Pool 16 for resistance to this disease. Under another cooperative arrangement (for development of resistance to the stunt diseases), the first cycle of selection was completed in four populations. Two of those are being handled by the national maize program of the Dominican Republic and the other two by breeders in El Salvador under the coordination of our pathology unit.

Corn stunt and bushy stunt (which are prevalent throughout the lowland tropics of Latin America, particularly in Mexico and Central America) are somewhat more complicated than some of the diseases for which the Maize Program has already developed good resistance. Much remains to be discovered about the relative importance of the stunt diseases in particular regions, about any differences in virulence that may exist within and between the mycoplasmas that cause them, and about the mechanisms and inheritance of resistance. As a start toward elucidating those issues, the Maize Program participated during 1986 in a cooperative project with The Ohio State University and distributed a stunt disease nursery to the Dominican Republic, El Salvador, Mexico, and Nicaragua.

It is important that the Maize Program should have numerous options in disease resistance breeding, since the disease situation in developing countries is extremely dynamic. A case in point is the tar spot disease syndrome. Until quite recently it was widely thought to be limited more or less to the special environments of experiment stations, but it now poses a growing threat to maize production from Mexico to Central America and has been found as far south as Ecuador. This year the pathology and advanced units initiated a project for incorporation or development of resistance in four materials. An experiment on chemical control of the disease was also begun to provide protection in the short term at experiment stations and in regions where fungicides are available to farmers. As with the stunt diseases, we also initiated some basic studies of tar spot to augment our currently limited knowledge of its causal agents and their exact role in disease development.

Germplasm bank—Much of the new work in the backup and other units of the Maize Program requires an extensive search for sources of resistance. Some of those might be found in the germplasm bank, which contains accessions of landraces and other materials that were employed in the original formation of many of our pools and populations. During 1986 samples of those materials were sent in 56 shipments to 21 countries and also made available to various units in the Maize Program. In addition, we returned excess seed of some accessions to their countries of origin.

As reported in the *1985 Annual Report* and *Research Highlights*, we have taken several actions during the last two years to better document the accessions and to make detailed information about them more readily available to maize researchers. Good progress was made this year toward fulfilling that goal. All the available information about most bank accessions has been reviewed and placed in our new computer data management system. By 1987 information on the rest of the accessions should also have been entered and printed out in the form of three draft catalogues, one each for accessions from Mexico, Central America and the Caribbean, and South America. This information, once it is published and distributed, should save researchers considerable time and effort in their search for resistances and other traits.

Associate scientist Renée Lafitte uses a portable photometer to measure chlorophyll content (an indicator of nitrogen status) as part of a program for improving nitrogen-use efficiency in maize grown under low supply of this nutrient.

Some of the bank's other activities are intended to expand our knowledge about accessions of maize and its wild relatives. Part of that work, such as maize race evaluations begun in 1986, can be done routinely by our own staff, while certain special projects will be executed in cooperation with other institutions. We are already receiving valuable help from groups outside CIMMYT in growing bank accessions for regeneration of seed. During 1986 regenerations were continued at headquarters and were also conducted by Pioneer Hi-bred International in Florida, USA, and by Ecuador's National Institute of Agricultural and Livestock Research.

Plant breeder David Jewell examining materials handled by the maize wide cross unit.

Wide crosses—Another source of traits (especially those for which there is insufficient or no variability in the maize crop) is the wide cross unit, which attempts genetic transfer of desired characteristics into maize through crossing with its wild relatives. The products of this work are intended to be readily usable and, unlike most germplasm bank accessions, should not be characterized by an unacceptable plant type that makes their incorporation into a maize improvement program somewhat difficult and time-consuming. Developing immediately useful wide cross materials, however, is itself a long-term process that is complicated by the differing genetic complexity of the various desirable traits.

The wide cross unit is currently devoting most of its efforts to hybridization of maize and *Tripsacum*. This highly variable genus is of considerable interest to us as a source of beneficial genes. It is widely adapted and tolerant to different soil and climatic conditions and possesses resistance to certain foliar diseases and insect pests, particularly the tropical maize stalk borers and fall armyworm. Since there appears to be no lack of variability in the Maize Program's germplasm for resistance to the foliar diseases, we are concerned primarily with evaluating and transferring the insect resistances into maize.

Since the early 1980s, we have been developing a procedure for transferring *Tripsacum* genes fairly quickly into tropical and subtropical maize. In 1983 part of a tripsacoid maize population with temperate adaptation (obtained from the University of Illinois in the USA) was combined with our subtropical Population 47 in an effort to improve the resistance of the latter to the southwestern corn borer. By 1986 the resulting materials had intermediate levels of resistance and a reasonably good plant type and were thus ready to be turned over to the backup unit. Such conversions of temperate tripsacoid materials to tropical or subtropical adaptation, though potentially useful, are a short-term activity, however. Our more distant objective is to develop tripsacoid populations that have tropical and subtropical adaptation from the outset and to transfer insect resistance from them to maize.

The advanced unit and international testing—The assembly of much new resistant germplasm, as described in the foregoing sections of this report, raises a number of important questions. How, for example, will we coordinate the diverse operations carried out by various groups in the Maize Program to develop and improve resistant materials? Even more important, how exactly will those materials reach maize breeders in developing countries?

Accomplishing the first task has required that the backup unit adopt a role it has not generally performed in the past. One of its main functions, beginning this year, is to deploy resistance developed by other units, along with that already available in our germplasm, among special-purpose pools that are adapted to the particular mega-environments for which those resistances are needed. Another of its functions will be to coordinate the breeding efforts required to maintain or raise resistance levels in those pools, while improving them for agronomic traits.

Once the agronomic quality of the resistant materials is considered satisfactory, they will either serve as sources of traits to be introgressed into advanced unit populations or will become advanced populations in their own right. Those materials will be further refined and prepared for distribution through the population improvement and variety development scheme that continues to be the core of our maize breeding program.

The advanced unit, which has primary responsibility for that work, improves the populations for a wide range of traits (yield, husk cover, and resistance to certain diseases, for example). The unit also conducts trials to determine the degree and nature of progress in population improvement, as illustrated this year with studies of materials that have undergone many cycles of selection for early maturity and others for drought tolerance. In addition, the advanced unit is providing guidance to the backup and other units concerning germplasm needs in developing countries.

Much of the information on which we are basing decisions about priorities in germplasm development has been generated by the mega-environments study begun in 1985 by the international testing program. By the end of this year, we had received responses for about 80 percent of the developing countries that produce significant amounts of maize. Starting with sub-Saharan Africa, we began organizing the information and presenting it in the form of maps and accompanying tables for immediate use by Maize Program staff. This year we also initiated a related study in which we are collecting data from experiment stations in sub-Saharan Africa on rainfall, temperature, amount of sunlight, soil types, and a number of other conditions over the past five years. Taking into account the marked differences in many respects between experiment stations and farmers' fields, we will use that information to check the impressions about maize production that were conveyed to us by our maize specialists and their colleagues in national programs as part of the mega-environments study.

As new germplasm is made available by our breeding units and regional programs, the international testing system will be called upon to provide new avenues for the free exchange, evaluation, and use of these improved materials.

Though extremely important, this effort to characterize maize-production environments in developing countries is secondary to the main task of the testing program, which is to provide a channel for distribution of experimental varieties and the elite fractions of populations. The program's main vehicles for disseminating that germplasm are International Progeny Testing Trials (IPTTs), in which full-sib families from a particular population are evaluated at up to six locations, followed by Experimental Variety Trials (EVTs) and Elite Variety Trials (ELVTs), which test varieties formed on the basis of IPTT results sent to us by trial cooperators in developing countries (see Appendix I for details on trial distribution).

As greater volumes and more varied types of germplasm are made available by our breeding units and regional programs, the international testing system will be called upon to provide other avenues for the free exchange, evaluation, and use of improved materials. The program's involvement this year in international testing of the MBR pool developed by the entomology unit is one illustration of how such new arrangements for testing are being made.

Special Categories of Germplasm

Much of the new material that will soon require international testing is being generated by the several groups in the Maize Program that are handling special categories of germplasm. To accommodate the influx of new materials, the international testing program anticipates an expansion in its activities and is currently developing various trial types in addition to the ones already in use.

Quality protein maize—Over the past four or five years, the international testing program has coordinated the evaluation of a large collection of special germplasm developed by the QPM program. This germplasm carries the opaque-2 gene (responsible for marked improvement in protein quality) but without most of the serious defects of opaque-2 materials formed in the early 1970s. International testing has been extremely valuable in further refining the QPM germplasm, particularly in disease resistance, wide adaptation, and stability of the genetic modifiers that have given QPM a far more acceptable grain type than was possessed by the original opaque-2 materials. This testing has also provided an opportunity to share the materials with breeders in developing countries and to get their reactions about its performance and utility.

One limitation of that germplasm, however, is that very few researchers in developing countries will be able to cross QPM with locally adapted germplasm and make selections. Such steps would require continual monitoring of changes in the amino acid balance by a laboratory specially equipped for protein quality analysis, which most developing countries do not have. Thus, in a rare exception to its policy of developing intermediate products, the Maize Program is in the position of having to provide final products for release to farmers. That being the case, we must target QPM materials very precisely for areas in which they might be especially beneficial in the human diet and in livestock feed.

An important implication of this policy is that resistance to certain diseases will have to be incorporated into selected QPM materials. Toward that end two tropical QPM pools were inoculated with ear rot and stalk rots this year for resistance selection, and four subtropical pools were screened for resistance to turcicum leaf blight and common maize rust. Other materials were converted to streak resistance through introgression of the corresponding normal germplasm that carries this trait. More exact tailoring of QPM to particular mega-environments will also require intensive testing in target areas under cooperative arrangements with selected national programs. The breeder responsible for this work made a start toward establishing such relationships by visiting Ethiopia in 1986 to discuss the potential contribution of QPM to the country's maize production.

International trials like this one in Ivory Coast are the Maize Program's main channel for distribution of improved germplasm.

Highland maize—This work, as explained in the 1985 *Annual Report* and *Research Highlights*, has been reoriented from a more or less exclusive preoccupation with floury and morocho highland maize for the Andean region to a primary emphasis on the semident types preferred by highland farmers in other parts of the world. The floury and morocho maize germplasm, developed and improved by a CIMMYT breeder based in Ecuador from 1978 to 1985, is currently being handled by the national program in that country with support from our specialists in the Andean region. Staff at Center headquarters, where our highland program is now based, are assisting Ecuadorian scientists as well, particularly in improving the materials for ear rot and corn earworm resistance.

The reoriented program's first order of business was to characterize the various highland environments and identify their germplasm requirements. That task was essentially complete by the end of 1986, although the information we have will, of course, be continually updated. According to our current estimates, there are nearly 5.5 million hectares of highland maize in developing countries, which we divide into three categories: 1) tropical highland maize, of which an estimated 3,424,500 hectares are grown at 2000 to 3600 meters above sea level, 2) tropical transitional zone maize, covering 1,913,000 hectares at 1300 to 2200 meters, and 3) temperate highland maize, occupying 135,500 hectares between 1000 and 2500 meters. These categories of maize are further distinguished by a number of other factors, including daytime and nighttime temperatures during the growing season, disease pressures, and so forth.

The program has already begun developing pools and populations for all three main types of highland maize environments. Most of our resources, however, will be committed to germplasm for the tropical highlands, since they are the most extensive of the three environments, occupying 63 percent of the world total.

Mexico contains a quite large share of the world's tropical highlands, so naturally we are developing close relationships with highland maize breeders in our host country and are concentrating heavily on its germplasm needs. Our primary aim will be to supply breeders with materials that respond well to nitrogen fertilizer and in other respects are better suited than the currently available germplasm to more intensive, mechanized maize production. The new genotypes will need to be shorter and more tolerant of high plant densities and have better root and stalk quality than materials now being cultivated. By crossing exotic with Mexican germplasm, we hope to develop more efficient plant types with those traits, while retaining the outstanding cold tolerance, partial tolerance to hail damage, and other useful traits present in the tropical highland germplasm.

A substantial part of the highland maize breeder's time was devoted this year to training and to consultation with maize breeders from areas that show high potential for production of highland maize. We are hopeful that those contacts and others made by our regional staff will lead to cooperative arrangements in which national scientists can assume the leadership in highland maize improvement for key regions.

Midaltitude maize—Maize of this type (which, like highland maize, is widely grown in eastern and southern Africa, but at 900 to 1500 meters above sea level) is the focus of a new germplasm development program initiated in 1985 under a cooperative agreement between CIMMYT, the University of Zimbabwe, and IITA. During 1986 the breeder and entomologist working at the Midaltitude Maize Research Station at Harare, Zimbabwe, divided their time among five main activities: 1) becoming familiar with the region's midaltitude environments and visiting the breeding programs that are developing germplasm for them, 2) designing and constructing research facilities, 3) hiring staff, 4) initiating the maize breeding program, and 5) laying the groundwork for mass rearing of and artificial infestation with the vector of streak virus.

Mexico contains a large share of the world's tropical highlands, so naturally we are developing close relationships with highland maize breeders in our host country and concentrating heavily on its germplasm needs.

Good progress was made in all of those activities, including the evaluation of a quite large collection of germplasm in hundreds of trial plots. Within a fairly short time, we expect this station to become a major tributary feeding improved midaltitude germplasm into our international testing program, which in turn will distribute the material to eastern and southern Africa and other regions of the world where this type of maize is grown.

Hybrid maize—In addition to distributing improved germplasm, CIMMYT provides much information about these materials that enhances their value to breeders in developing countries. Generating such information is an especially important task of our hybrid maize program, which was established in 1985 to meet the growing demand for assistance in hybrid breeding. During 1986 the program was engaged in a number of activities that are leading to the development of new germplasm products and information about them or about other materials already available.

One of those activities is to provide data on the combining ability of our germplasm that will give breeders some indication about its utility in hybrid formation. For that purpose the various pools and populations were divided into eight groups during 1985, diallel crosses made within each one, and the diallels evaluated in 1985 and 1986. From the results of those evaluations, we now have a general idea of which materials combine well and will publish that information during 1987. In an effort to improve the cross performance of some of those materials, we shifted Populations 21 and 32 from the advanced unit into the hybrid program where they will undergo interpopulation improvement. From those and other pools and populations, the program is also attempting to develop source germplasm that is tolerant to inbreeding depression, so that breeders employing these materials will stand a better chance of extracting good inbred lines from them.

Regional maize workshops provide the direct and continuous contact between scientists in developing countries that is a precondition for the emergence of regional strategies in agricultural research.

In more or less the same set of pools and populations, we continued a project begun in 1985 for developing our own early generation inbred lines. Some of the most promising ones identified so far are being screened for insect resistance by the entomology unit and for drought tolerance by the physiology unit, while others are being evaluated and further inbred by researchers in developing countries. We are taking a number of the inbred lines and other materials a step further by forming single-cross hybrids (whose performance enables us to predict good combinations for three-way and double-cross hybrids, among other purposes). We also developed and evaluated various types of nonconventional hybrids, in which by definition at least one of the parents is not an inbred line. Because the nonconventional types are somewhat simpler and less expensive to produce than the conventional ones, we consider them a good intermediate step for maize programs that have only recently initiated hybrid breeding.

Training

The Maize Program's efforts are divided more or less evenly between generating research products and strengthening the capacity of maize scientists in the Third World to employ these and other resources effectively. One of our primary means of accomplishing the latter objective is to offer various training programs at Center headquarters, including in-service courses and fellowships for predoctoral candidates, researchers who have just received their doctorates, visiting scientists, and associate scientists (see Appendix III).

Completion this year of the Borlaug Building and the donation of several grants has enabled us to open up new maize training opportunities. With funds from various governments and from private seed and chemical companies, we are providing approximately 45 new one- to four-month visiting scientist fellowships from 1986 through 1988 for senior researchers in Third World countries. In addition, we are expanding our in-service maize breeding and production agronomy courses to include training in the use of microcomputers for data analysis, with equipment provided by a private company.

Several other adjustments were made in those courses to improve the quality of instruction. Starting in 1987, for example, the six-month courses will be offered in only one language during a given cycle (one cycle taught in Spanish for every two in English), a change that will double classroom time and greatly simplify field activities. The scheduling of the cycles is also being altered in such a way that trainees will receive more experience in planning on-farm research. Finally, for the first time since maize training was initiated at CIMMYT, a breeder will be devoting full time to the course in crop improvement, a development that should greatly enrich the training experience of participants.

One beneficiary of those training activities is the Maize Program itself. Visiting scientists and course participants have much to teach us about maize research challenges in their countries, and in doing so they provide us with valuable guidance in setting priorities. Another group that contributes substantially to the Program is pre- and postdoctoral fellows and associate scientists, of whom there were eight during 1986, conducting research on nitrogen-use efficiency, various diseases, hybrid development, and analysis of yield stability.

Regional Programs

Several staff changes took place, and one important adjustment in organization was made this year in the maize regional programs, of which there are currently six: 1) Andean region, 2) Asia, 3) eastern Africa, 4) Mexico, Central America, and the Caribbean, 5) the Middle East/North Africa, and 6) southern Africa. The Asia and Andean regional programs each acquired one extra specialist, and a new staff member joined us from Thailand's national program to take the place of a specialist transferred from Turkey to Colombia. The addition of other regional specialists to our staff in sub-Saharan Africa has enabled us to divide one program into two, with one for eastern and another for southern Africa. By 1987 the former will be staffed by one breeder and two agronomists based at Nairobi, Kenya, and the latter by a breeder and one agronomist operating from Harare, Zimbabwe. The division of what was a very large and diverse region into two smaller ones, along with the additional staff, will result in a much-needed increase in our level of support to African national programs.

Apart from the two regional programs, we have three breeders in West Africa and a fourth in Zimbabwe, who are engaged in germplasm development activities and training. They in effect manage distant branches of the headquarters breeding effort and work closely with, but do not form a part of, our regional and bilateral programs (for details on the bilateral projects, see the reports on extra-core grants).

In other sections of this report, we have pointed out some of the vital contributions of the regional programs. An important one is the gathering of information needed for research planning and other decisions at CIMMYT headquarters. It was largely at the urging of scientists in the Asia region, for example, that we held a conference on aflatoxin this year in Mexico, the proceedings of which will be available in 1987. Other important functions of the regional programs are to organize in-country training activities and assist national maize programs in germplasm development and other research.

Rather than give a comprehensive account here of the numerous ways in which each of our six regional programs provided those services this year, we cite several representative examples. Fairly typical of the regional agronomy work were the three on-farm research courses offered to about 30 research and extension workers in Colombia and an equal number in Paraguay. Regional specialists concentrating on crop improvement were engaged in parallel activities, such as the two-week maize breeding and production course, covering the fundamentals of maize improvement, that was given in Zambia for 38 persons. Through those and other means, the maize specialists provided individualized attention to maize programs in most developing countries where significant amounts of maize are produced and consumed.

Much of their energies also went into activities designed to promote regional cooperation in maize research. Four of the six programs, for example (Asia, Andean region, Central America and Caribbean, and Middle East/North Africa), held regional workshops, and the two others (eastern and southern Africa) began planning a workshop to take place in 1987. Because these are regular events, they provide the direct and continuous contact between scientists in developing countries that is a precondition for the emergence of regional strategies in agricultural research. The cooperative activities encouraged by the workshops vary in their forms and objectives from one region to another. The Andean meeting, for example, provided a forum for discussing an international initiative for development of tolerance to aluminum toxicity, a region-wide constraint of maize production. For the meeting in Asia, superior germplasm from 14 countries in the region was planted in Indonesia, the country hosting the workshop, so that participants could examine the materials and make seed requests.

Participants in the Second Asian Regional Maize Workshop during a visit to a seed production plant in Indonesia.

Wheat Research

During 1986 bread wheats, durum wheats, and triticales with the Center's germplasm were planted on more than 45 million hectares in the Third World and another 15 million hectares in developed countries. The tremendous surge of improved germplasm since the early days has truly transformed the agricultural scene of many cooperating countries. With the proper agronomic practices, it has helped double and even triple the wheat production of many developing countries, contributing to raised standards of living for millions of people.

It is interesting to note that the bread wheat, durum wheat, and triticale breeding programs have even longer histories in Mexico than the Center itself. Bread wheat breeding completed its 43rd year in the country in 1986. The first efforts in durum wheat breeding started in the early 1950s, with major work starting in the late 1960s. Triticale breeding began in 1965. The new winter wheat improvement program based in Turkey started in 1985.

Crop Improvement Programs

Shuttle breeding and multilocation testing are key strategies that come into play for all four crop improvement programs.

The Wheat Program has developed a range of widely adapted germplasm appropriate for Third World production conditions through a "shuttle breeding" strategy combined with extensive international multilocation testing. In the shuttle breeding concept, germplasm is crossed, screened, and selected during winter and summer cycles each year at two diverse locations in Mexico. Advanced generation breeding materials that have passed the rigors of selection at both locations are then entered into nurseries for international testing and distributed to cooperators around the world.

In 1986 collaborating scientists in 97 countries were sent 2628 sets of bread wheat, durum wheat, and triticale nurseries (see Appendix II). In addition, in cooperation with the International Center for Agricultural Research in the Dry Areas (ICARDA), CIMMYT prepared and distributed 255 sets of barley nurseries for testing in 66 countries. The information returned by the cooperators helps the Program to plan future crosses as well as set the priorities and direction of the three programs. This research methodology, using the information derived from the international nurseries in the Program's crossing program in Mexico, followed by the selection of superior advanced genotypes at testing sites in Mexico

H. Jesse Dubin (left), pathologist/breeder (based in Nepal), and Arthur Klatt, associate director of the Wheat Program, inspect wheat plots at the Phrae Rice Research Center, Thailand.

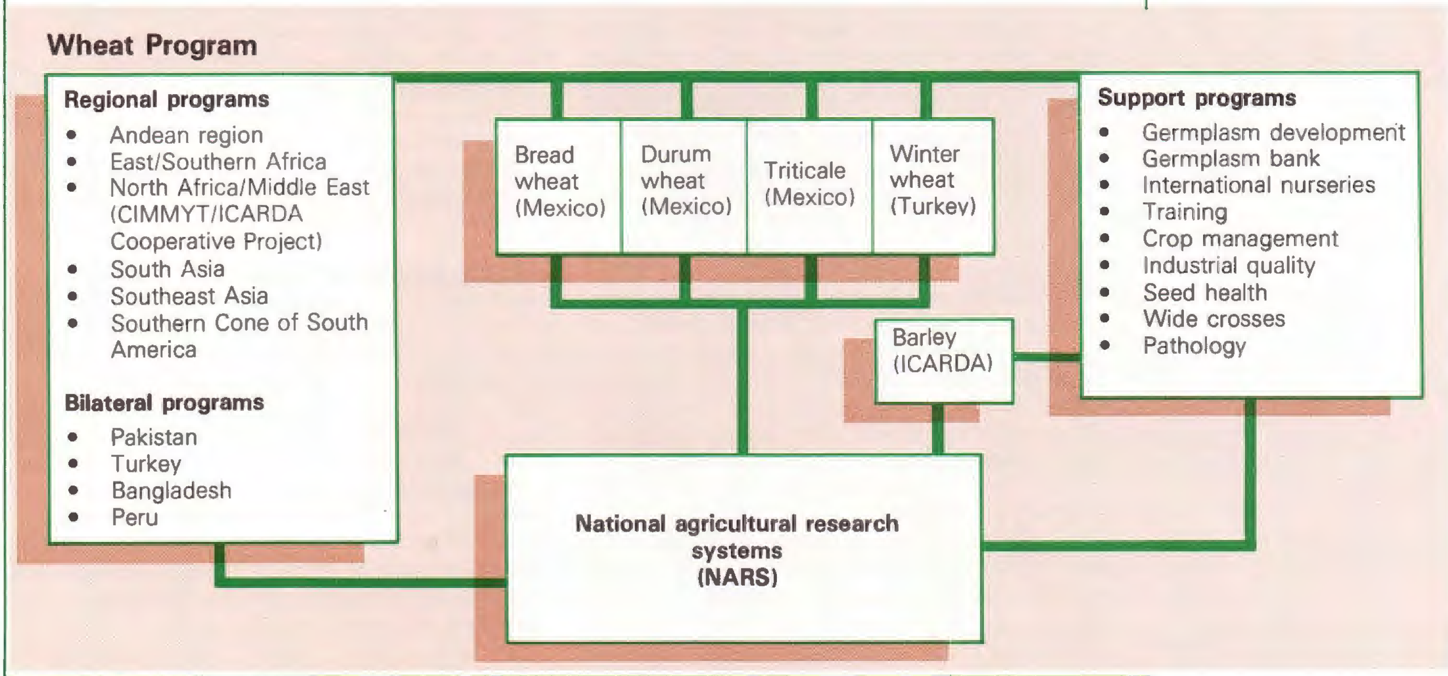
Activities and Structure of the Wheat Program

The CIMMYT Wheat Program conducts research at headquarters in Mexico, Turkey, and regional and national programs. There are 20 international staff at headquarters working in the three crop improvement programs in bread wheat, durum wheat, and triticale and the nine support programs; two staff members in Turkey work in the winter wheat improvement program (see the diagram). At the end of 1986, 11 wheat specialists were assigned to six regional programs and four others were assigned to four bilateral (national) programs.

The four crop improvement programs are the core of the Wheat Program. The germplasm developed in these programs is distributed to collaborating scientists in national agricultural research systems (NARS) through the international nurseries. This process is only complete when NARS scientists have selected and refined this germplasm to suit specific local needs, and have successfully extended new varieties to farmers.

The research done within Mexico and Turkey is reinforced and complemented by CIMMYT's regional and bilateral programs. The Program's outreach staff play a vital role in developing and disseminating its research products. Working with NARS personnel, outreach staff help identify regional and national needs, expedite the exchange of germplasm, participate in an advisory capacity in crop improvement and crop management research, and assist with the training of technical personnel from national programs. The exchange of information among NARS scientists and CIMMYT staff in Mexico, Turkey, and elsewhere abroad is crucial for the rapid development of widely adapted, improved wheats suited to a wide range of environments.

The nine support programs at headquarters, not only serve the crop improvement, regional, and bilateral programs, but also provide the NARS with a wide array of technical assistance in breeding, pathology, crop management, and training. The ICARDA barley breeder posted in Mexico also makes use of these support services in the development of barley germplasm for the NARS.



and other locations, has proved to be an extremely effective breeding strategy for bread wheat, durum wheat, and triticale improvement.

The shuttle breeding technique that has proven to be so effective in Mexico is also working extremely well on an international basis. The best example has been CIMMYT's 13-year collaboration with Brazilian scientists to develop high-yielding wheat varieties with tolerance to the problems of acid soils. In 1986, CIMMYT began a small-scale shuttle breeding project between Mexico and China to develop scab-resistant spring wheats for the Yangtze River Valley. International shuttle breeding projects were also expanded to include Kenya and Ethiopia (resistance to the rusts), and Nepal (helminthosporium resistance).

In 1986 the process of identifying and describing the mega-environments for which the Wheat Program develops its materials continued. Through the years this task has been an evolving process as more information has become available.

In 1986 the process of identifying and describing the mega-environments (agro-ecological zones) for which the Program develops its materials continued. Through the years this task has been an evolving process as more information has become available on the predominant characteristics, such as moisture availability, biotic and abiotic stresses, and soil types, that differentiate one mega-environment from another. As a result of this ongoing exercise, the mega-environments discussed below, as they relate to the crop improvement programs, have been and will continue to be refined.

Bread wheat improvement—The bread wheat program is the largest of CIMMYT's small grains improvement efforts, a priority that is in keeping with the fact that about 61 percent of the developing world's wheat area is devoted to spring bread wheat. The Center maintains a broad genetic base in its bread wheat germplasm for such traits as yield, wide adaptation, resistance to the major diseases, and milling and baking quality. In addition, the germplasm base contains subsets of materials having especially desirable traits, such as resistance to "minor" diseases of wheat and tolerance to such stresses as drought and the problems of acid soils.

In 1986 the bread wheat program continued to refine the identification and description of the five mega-environments for which it has devised different research agendas to support national programs.

Well-watered environments with no obvious soil problems occupy approximately 60 percent of the Third World's spring bread wheat areas. Rusts, powdery mildew, and in certain cases, septoria tritici blotch are prevalent.

More than 20 million hectares (about 20 percent) of the developing nations' spring bread wheat areas are found in high-temperature environments, including rice-wheat rotation areas. In 1986 the bread wheat program continued its research on the problems encountered in attempting to produce wheat in warmer, more tropical production environments. In addition to focusing on the development of greater resistance to certain diseases, this breeding effort is giving attention to improving tolerance to heat stress, which can adversely affect tillering and grain filling abilities of wheat grown in warmer environments. Helminthosporium, fusarium head scab, and the rusts are the main disease constraints in this environment.

Semiarid environments occupy about 15 million hectares of developing country bread wheat areas. Drought resistance and heat tolerance are major breeding constraints. Some spring x winter materials are showing improved tolerance to drought and may be a promising avenue of exploration. Advanced lines are now being selected under reduced moisture regimes, and the best of these lines are distributed through the international nursery program for additional testing.

Mineral toxicities/deficiencies associated with acid soils are a problem on less than 5 percent of the Third World's spring bread wheat areas. Aluminum toxicity is usually the main problem in this mega-environment. In order of importance, the rusts, the septorias, head scab, helminthosporium, and barley yellow dwarf virus (BYDV) are the main disease constraints. A number of high-yielding bread wheat lines with tolerance to the problems of acid soils and with improved resistance to the diseases found in these environments are being developed through the shuttle breeding program with Brazil.

Approximately 27 percent of the developing countries' bread wheat areas are in what could be described as a winter wheat mega-environment. In 1985-86, CIMMYT began a winter wheat program on a partnership basis with Turkey (see the section on winter wheat improvement for more details).

Durum wheat improvement—The importance of durum wheat as a major basic food is well established for most of the countries of North and East Africa and the Near and Middle East. It is also important in the Asian Subcontinent and the Andean region and is a major crop in Argentina, Canada, Chile, the USA, and several countries of southern and eastern Europe.

The area planted with durum wheat worldwide covers approximately 30 million hectares, with about 11 million in developing countries. Production of durum wheat in these Third World nations is approximately 10 million tons annually. Large production areas of North Africa, the Middle East, and the Southern Cone of South America reflect a low average yield resulting from cultivation in mainly dry areas under rainfed and semiarid conditions. This low yield also illustrates that the crop is often poorly managed and that the cultivars available to the farmers are often susceptible to one or more major diseases.

Progress has been made in improving the level of disease resistance in CIMMYT's durum wheat germplasm for stripe rust, powdery mildew, and septoria nodorum blotch. This can be demonstrated by the disease score results of the entries of the 14th Elite Durum Wheat Nursery (EDYT) and 16th International Durum Wheat Yield Nursery (IDYN). However, the mean disease reactions for spike infection of stripe rust, leaf and stem rusts, septoria tritici blotch, head scab, and BYDV suggest the need to further increase the genetic variability for disease resistance.

Shuttle breeding is especially useful in durum wheat germplasm development when the severity or magnitude of the selection pressure for one or more traits at one research site is not representative of that present worldwide. This is particularly true for diseases, in that it is very rare to find all of the important pathogen variability at any one location. This is most evident with the rusts (stem, leaf, and stripe).

Breeding objectives continue to be the development of high-yielding, management-responsive, and input-efficient germplasm that is disease resistant, has good quality traits, and is tolerant to environmental and soil stresses. To accomplish these objectives, the durum wheat breeding program has identified five mega-environments worldwide.

The mega-environment characterized by well-watered lands encompasses about 20 percent of the durum wheat areas of the developing nations. These environments can be irrigated, have high rainfall, or have low rainfall with supplemental irrigation. The relatively high program effort with this mega-environment is due to preliminary data that suggest that certain genotypes perform well in both well-watered and stress environments, and due to the severe disease pressure commonly encountered in this mega-environment.

Pedro Brajcich, head of the durum wheat program, selects durum wheat for seed quality during the Toluca cycle.

Semiarid environments with drought stress encompass about 40 percent of the durum wheat areas of the developing nations. These areas have less than 400 millimeters of rainfall annually. As a test of newly advanced germplasm for drought tolerance, the 17th International Durum Screening Nursery was planted in two locations at Ciudad Obregon in 1985-86 to simulate both full and limited irrigation. Data indicate that selection under full irrigation also helps to identify lines that do well under stress conditions.

Thomas Barker, postdoctoral fellow in the triticale breeding program, makes selections during the 1986 Toluca cycle.

Highlands (more than 1000 meters above sea level) encompass about 10 percent of the durum wheat areas in the developing world. The rusts, septoria tritici blotch, septoria nodorum blotch, leaf blight, head scab, root rot and powdery mildew are the major disease problems. Minor element toxicity/deficiency caused by low pH soils is also a constraint.

Environments where some cold tolerance is required encompass about 10 percent of the durum wheat areas in the developing nations. The rusts, septoria tritici blotch, leaf blotch, head scab, root rot, and common bunt are disease problems. Durum wheat producing areas within this mega-environment require differing levels of tolerance to cold temperatures. Therefore, in 1986 crosses were initiated between CIMMYT's best lines and winter durum wheat cultivars from Germany, Turkey, France, Austria, Italy, Romania, and the USSR.

Winter or facultative durum wheat areas encompass about 20 percent of the durum wheat areas of the developing nations. The newly established winter wheat improvement program in Turkey (described in the winter wheat improvement section below) will also give attention to durum wheat. The durum wheat program also uses lines from the area as a source of variability for cold tolerance and an additional gene pool for disease resistance, drought tolerance, and quality.

Triticale improvement—The first commercial triticale varieties were released 18 years ago in Hungary, Spain, and Canada. In 1986 the crop was grown in some 32 countries on just over 1 million hectares.

Because triticale is a manmade crop (the successful hybridization of wheat and rye), its genetic variability is much more restricted than that of crops such as maize and wheat, which originally evolved in nature over long periods. In addition, excessive use of a few varieties, which in the early stages were more promising, further restricts this variability. Thus, the threat of genetic vulnerability is more acute in the case of triticale than any other crop. CIMMYT is working to rectify this problem by combining the variability from the putative parents, as well as from winter triticales, as a separate gene pool.

Since 1984 greater priority has been given to expanding the variability of the germplasm base. In 1986 approximately 34 percent of the crossing efforts (compared to 16 percent in 1984) were directed toward creating additional variability through interspecific crossing and the production of primary triticales. In addition, 21 percent of the crosses (compared to 6 percent in 1984) were between spring and winter triticales. This shift in emphasis will continue, and the expansion of the genetic base shall be treated as a principal objective for the foreseeable future.

Two major target areas identified for triticale improvement are acid soils/tropical highland environments and semiarid conditions. Well-watered areas have been identified as a third mega-environment of lesser importance in the triticale program. Now that these areas have been targeted, strategies are being designed for enhancing the potential adaptation of the germplasm to each of them.

From a breeding standpoint, tropical highlands and the acid soils with aluminum toxicity have many characteristics in common, and hence they are treated as a single mega-environment. Free aluminum ions (toxicity), unavailability of phosphorus, insufficiency or toxicity of minor elements, high humidity during the crop ripening phase, and presence of numerous diseases are typical of this mega-environment. The adaptation of triticale to these conditions is probably due to the presence of the rye genome. Resistance to sprouting and the capacity to maintain good smooth seed after the ripe crop is subjected to excessive rainfall are important characters for the acceptability of triticale.

Tolerance to head scab, helminthosporium spot blotch, and septoria nodorum blotch and resistance to stripe rust, stem rust, and leaf rust are also important for the viability of the crop in this mega-environment. The germplasm development activity of the triticale program attempts to incorporate variability for all these diseases from bread wheat, durum wheat, and rye.

Stability of yield and test weight under drought conditions are the two prime considerations in developing material for semiarid conditions. Diseases are not considered a major factor; however, care is taken so that the material is fairly broad based for resistance to the rusts and septoria.

Major dryland areas in the developing world with potential for triticale cultivation are in North Africa and the Middle East, parts of China, central India, the dry areas of Afghanistan, and parts of Sind and Baluchistan Provinces in Pakistan.

Segregating populations based on lines and varieties showing high test weight and yield under drought environments in Mexico are shuttled three times through Huamantla, a drought-prone location with sandy soils, and Ciudad Obregon under limited irrigation (no irrigation results in total crop failure). During each cycle populations are eliminated based on the mean value of all the plots for yield and test weight. Populations selected under drought stress are then planted at the F_5 stage under optimal conditions to identify plants with higher genetic yield potential. Plants so selected are reevaluated under various drought situations before they are included in international nurseries, which are sent to many drought-prone areas. In 1986 the first group undergoing this selection procedure was at the F_5 stage.

Since 1984 greater priority has been given to expanding the variability of the triticale germplasm base. This shift in emphasis will continue, and expansion of the genetic base will be treated as a principal objective for the foreseeable future.

Yield levels of triticale in well-watered areas are comparable to those of durum and bread wheats. Lower test weight and lack of a market discourages expansion of triticale in this mega-environment. However, under special circumstances in some of the high-production environments, such as the areas in Mexico, India, and Pakistan with Karnal bunt, triticale might be a good alternative to wheat.

Germplasm under development for the acid soils/tropical highland and semiarid mega-environments is cycled through, and evaluated at, various stages in high-production environments. This permits the program to identify lines having potential for the well-watered areas. In addition, a small portion of time is devoted to developing substituted triticales with high yield potential, rust resistance, and industrial quality.

Winter wheat improvement—Large areas of the developing world depend on winter wheat, and improved germplasm could contribute significantly to increased production. CIMMYT initiated its winter wheat program in 1985-86, and it is still quite small with only two core-funded staff members assigned and with limited input from national and regional program staff. Current financial resources allocated to winter wheat research represent 2 percent of the base budget and 14 percent of the total outreach budget. This 14 percent is primarily the costs of the two staff members in Turkey and the Turkish bilateral program. Winter wheat research currently commands 7 percent of the total budget.

The partnership with Turkey makes available a large array of scientific and financial resources with which to meet the needs for winter wheat in developing countries.

Obviously, winter wheat research deserves a greater input of resources, but part of this requirement is being obviated by the cooperative winter wheat program with Turkey. This partnership makes available a large array of scientific and financial resources with which to meet the needs for winter wheat in developing countries. Also, considering that a large portion of the total winter wheat area is in China, CIMMYT is negotiating with the Chinese Academy of Agricultural Sciences for collaboration in the overall winter wheat research effort.

In addition, a cooperative program on winter wheat research has been developed with Texas A&M and Kansas State Universities. These programs will supply germplasm and training. Although Oregon State University, formerly a large contributor of winter materials, is phasing down on international winter wheat research, it continues to be a close cooperator with CIMMYT in germplasm exchange and training of graduate students. The combined activities of Turkey, China, the USA, and CIMMYT should make an impact on winter wheat production in the near future.

To date, winter wheats originating from the Turkey/CIMMYT partnership have been evaluated. Superior lines selected for international testing in the International Winter Wheat Screening Nursery (IWWSN) were sent to 40 locations in 1986.

Also in 1986, a small winter wheat breeding project in Mexico complementing the larger program in Turkey was at the F_6 level. Some of these lines will be distributed in 1987-88 for evaluation.

Support Activities

Crop management—Improved crop management will play an increasingly important role in future gains in productivity and total production in many developing countries. Presently, germplasm exists with a yield potential far exceeding local production conditions, resulting in a large yield gap in many countries. To take greater advantage of the available genetic potential, improved crop management practices must be adapted. Certainly, the Wheat Program cannot conduct all the necessary research, but it can play a significant role in assisting national programs to organize research activities that address problems and reduce or eliminate production constraints. The input will involve technical assistance, consultation, and, to some extent, direct participation to motivate research efforts. Of course, training will play a significant role in motivating researchers and increasing the attention to crop management research needs.

In 1986 crop management represented about 20 percent of the Program's human and financial resources. If CIMMYT is to fulfill its stated mandate, then crop management has a significantly greater role to play.

Germplasm bank—The wheat germplasm bank maintains working collections of breeding materials primarily to support the research of Wheat Program scientists and national program collaborators. At the end of 1986, CIMMYT had 55,763 entries in its small grains bank, including 11,512 bread wheat, 4,824 durum wheat, 5,375 triticale, 4,837 barley, and 2,561 alien related species entries; the bank also contained 26,554 entries from other international germplasm banks.

Pathology—The Wheat Program's pathology efforts include a seed health unit, a global small grains disease surveillance program, and a special project focusing on BYDV (see the section on extra-core grants).

The seed health unit, established in 1984, provides a more comprehensive and coordinated approach to seed health problems for both the Maize and Wheat Programs. The unit works in close collaboration with the Mexican Plant Protection Organization (Sanidad Vegetal) and is responsible for all standard tests for seedborne pathogens in germplasm destined for international distribution, development of improved methods of detection of seedborne pathogens, experiments to determine the efficacy of chemical seed treatments, training in seed health, and determining improved seed treatment and methods.

A special research project within the unit deals with Karnal bunt, a disease of wheat and triticale caused by the weakly pathogenic fungus, *Tilletia indica*. At present quarantine restrictions apply to seed movement from Karnal bunt-infected areas in northwestern Mexico to other parts of the country and to international destinations. These restrictions hinder germplasm exchange. Entries in the Karnal Bunt Screening Nursery, grown at four locations during the 1985-86 season in the Mayo and Yaqui Valleys under natural and artificial infection, comprised the best bread wheat, durum, and triticale lines from previous screening. The best lines identified will be further tested at 10 to 15 locations in Karnal bunt areas of Mexico and at sites in India, Pakistan, and Nepal, during the 1986-87 season. During a smut and bunt workshop in April, more research activities were planned to broaden the knowledge base and to resolve some of the unknowns about the disease.

Since the 1970s, CIMMYT has conducted a disease surveillance program. This network of cooperators has helped monitor and survey prevalent diseases and races that exist throughout the world. Preliminary results of the survey have been distributed to cooperators. During 1986 work began to publish the complete data and analysis from the program. The results will help identify epidemiological zones around the world. It will also help scientists obtain some insight on the dissemination of new races from one country to another.

Wide cross research—Research in wheat wide crosses is devoted to improving disease resistance and stress tolerance in wheat by the transfer of useful genes from related genera of wheat. The program currently focuses on developing resistances to *Fusarium graminearum, Helminthosporium sativum*, and *Tilletia indica*; tolerances to saline and aluminum toxic soils; and copper deficiencies. Most of the wide crosses to date involve *Agropyron, Elymus*, and *Aegilops* species.

Interspecific crosses were initiated in 1986. Due to the existence of close phylogenetic relationships, ease of crossability, and

Peter Burnett, pathologist and head of the Barley Yellow Dwarf Virus Program, discusses advances in BYDV research at Toluca.

opportunities of a high recombination status, this work offers short-term payoffs (7 to 10 years) and, as a result, will now receive about 60 percent of the wide cross program's efforts. The more distant alien species contributing to the intergeneric area fit the long-term goals (15 years) and will now receive 30 percent of the program's attention.

Numerous hybrids have been produced and advanced to field testing. Resistances to *Fusarium* and *Helminthosporium* spp. as well as to Karnal bunt have been identified. Alien germplasm with tolerance to aluminum toxic and saline soils is being used for wheat improvement, as is alien germplasm with an efficient uptake of the copper micronutrient in copper-deficient soils. Callus culture is being used for in-vitro screening, inducing variation, and for alien gene introgression. Techniques involving the use of nonradioactive probes for D genome identification are available, and probes for other alien species are being developed. These will substantially aid the program in making alien gene transfers. Other diagnostic probes may be of value and will be assessed through future collaborative research.

New areas of research being considered include resistance to BYDV, septoria diseases, leaf rust, and powdery mildew. It is hoped that collaborative research will be developed in the following areas: isozyme analyses (USA and Australia); restriction fragment length polymorphism probes (USA and UK); and nonradioactive probes (USA). The technique employing nonradioactive probes for D genome applications in interspecific hybridization has been developed and will be transferred to CIMMYT.

Training

CIMMYT wheat training programs are characterized by close working relations between the Center's senior scientists and a limited number of trainees from national crop improvement and crop management programs in the developing world (see Appendix IV). Although trainees learn firsthand about the Center's methods and materials, the purpose of this training is not to transplant CIMMYT methodologies into national programs. Rather, the intention is to allow each national program, through the trainees that come to to the Center, to borrow as much of the research approach as is useful.

Wheat improvement—The main objectives of the wheat improvement training program are to:

- Impart to trainees the research skills and knowledge used at CIMMYT to develop improved germplasm
- Encourage and develop the trainees' ability to synthesize new forms of wheat technology
- Foster specific types of attitudinal change among trainees

Each trainee is assigned to a work team with a crop interest (bread wheat, durum wheat, triticale, or barley). With the objective of turning trainees into an "army" of crop improvement specialists, all trainees, regardless of their areas of specialization, are given the opportunity to work across disciplines at the field level. This process of integration includes all phases of germplasm development research, the theory and practice of cereal pathology, and important aspects of crop management.

From 1971 to 1986, CIMMYT has trained 335 scientists from developing countries in wheat improvement (breeding and pathology). The impact of this training on human resources in the developing world has been substantial. Today, breeders and pathologists trained by CIMMYT are active in over 100 national programs. Many of the research leaders in national programs today are former CIMMYT trainees and visiting scientists.

Production—The objective of the production training program is to develop an agronomist conversant with all aspects of crop management. Trainees are generally young wheat scientists from developing countries and generally have very little experience in research. Ideally, after the six-month course, trainees return to their research programs to execute a research program in wheat agronomy that is relevant to the agronomic and economic circumstances of their countries.

Trainees work on the experiment station and in farmers' fields. On-farm research is emphasized to maintain a high level of consciousness of the relevance of agronomic research to farmers' problems. Interdisciplinary competence is achieved through trainees' exposure to a wide range of field problems and through field and classroom lectures by CIMMYT staff from many disciplines. All steps in the research process are taught in a sequence ranging from problem diagnosis to research planning, field execution, agronomic and economic analysis, and extension.

In 1986 the production course was held for the 20th time. An increasing number of trainees are drawn from areas where wheat is not a traditional crop, such as Nigeria and Thailand.

Beginning in 1987, part of the field component of the course will be done near Chalco, where wheat is the main crop. The experiment station part of the course will be strengthened, because strong research on the station is essential to the success of on-farm research.

The course is now taught under dryland conditions, but an irrigation component will be incorporated in the future. More time will be spent on field diagnosis, on the basis of which trainees will be asked to design and implement a research program. Greater emphasis will be given to cropping systems in relation to wheat production; this segment of the course will be taught using case studies of situations encountered by CIMMYT agronomists in their work throughout the world.

Maria Teresa Nieto, a doctoral candidate from Spain, helps with emasculation in durum wheat plots at Obregon.

Regional and Bilateral Programs

The breeders, pathologists, and crop management specialists in regional and bilateral programs provide assistance to the development of national wheat research programs and, ultimately, to improving wheat productivity in developing countries. These program staff members are involved in crop improvement, training, and support to national programs.

Regional programs cover the major wheat-growing areas of the developing world:

- The Andean region
- East and southern Africa
- South Asia
- North Africa/Middle East (CIMMYT/ICARDA Cooperative Project)
- Southeast Asia (wheats for warmer and more marginal environments)
- Southern Cone of South America (wheats for warmer and more marginal environments)

Mahbub Uddin Ahmed (left), wheat pathologist with the Bangladesh Agricultural Research Institute (BARI) and former CIMMYT trainee, and a co-worker inspect Bangladesh Screening Nursery plots at BARI.

In 1986 the program's post in Lisbon, Portugal, for North Africa and the Iberian Peninsula was closed. The region will continue to be administered by CIMMYT personnel assigned to the CIMMYT/ICARDA Cooperative Project.

CIMMYT currently has bilateral programs in Pakistan, Bangladesh, Peru, and Turkey (see the section on extra-core grants).

Andean region—This regional program began in 1976 when CIMMYT posted a breeder/pathologist to Quito, Ecuador. Since 1982 a regional agronomist was part of the team. The primary goal of the regional staff has been to increase the productivity of resources devoted to wheat production in the region. The most obvious immediate measure of success is the fact that, in all traditional small grain-producing areas of the region, adapted and disease-resistant varieties with high yield potential are widely cultivated.

East and southern Africa—The nations of this region are seeking new areas in which wheat production can be established or expanded. The objectives of CIMMYT activities in this region cover three broad areas: 1) germplasm and human resources development, 2) networking and training, and 3) improved crop management techniques (see the section on extra-core grants).

South Asia—This program, based in Kathmandu, Nepal, was established in 1985 to: 1) focus on helping to minimize the possibility of wheat disease epidemics in South Asia and 2) assist national programs in germplasm development, training, technical backup, increased communication within countries and regionally, and small equipment requirements.

North Africa/Middle East—Since 1980 bread wheat improvement for North Africa and the Middle East has been a joint CIMMYT/ICARDA endeavor. The facilities and bread wheat breeding programs of both research centers are used to improve bread wheat germplasm for targeted marginal environments in the region.

Durum wheat is planted to about 70 percent of the total wheat area of this region. Since 1984, CIMMYT and ICARDA have had a joint durum wheat program with the aim of developing complementary durum wheat research at both institutions, coordinating germplasm distribution, and working closely with national programs.

In 1986 the Center laid the groundwork to create a new program in North Africa and by 1987 expects to have a specialist based in Morocco, where there will be special emphasis on triticale improvement.

Southern Cone of South America (wheats for warmer and more marginal environments)—The regional program for developing wheats for the warmer and more marginal areas in South America was initiated in 1986 and now has staff based in Paraguay. They are concentrating their efforts on developing wheats and technologies for the more tropical areas of Paraguay, Brazil, Bolivia, and Argentina. They will also give limited input to germplasm development for other countries of the Southern Cone. The challenge lies in identifying and screening appropriate germplasm that can adapt and produce under the high, dynamic disease and insect pressures at an economic level. Regional staff are working with the national programs to identify problems, set up priorities and goals, and assist in developing appropriate research strategies.

Southeast Asia (wheats for warmer and more marginal environments)—This regional program is based in Thailand and concentrates on developing germplasm and crop management research programs for Thailand, Indonesia, Burma, and the Philippines. To date working relationships with many of these countries have been established for the exchange of germplasm and information. Special international nurseries have been set up and distributed to national programs. An international conference entitled Wheat Production Constraints in Tropical Environments is scheduled for January 1987 in Chiang Mai, Thailand.

Pakistan—The bilateral program in Pakistan was established in 1976 with the general aim of strengthening wheat research in the country and giving more emphasis to agronomy. On-farm research has provided a better understanding of each selected cropping zone in the country and has helped focus work at the stations on relevant research issues.

Bangladesh—Wheat is the second most important cereal crop in Bangladesh. The bilateral program was initiated in 1982 and has three major components: technical assistance, training, and equipping the national program for research. Progress has been made in developing appropriately adapted, leaf-rust resistant, popular varieties to replace and/or effectively diminish the area occupied by the predominant commercial variety that is susceptible to leaf rust. Bangladesh also plays an important role in the regional tropical wheat effort.

In 1986 the Center laid the groundwork to create a new program in North Africa and by 1987 expects to have a specialist based in Morocco, where there will be special emphasis on triticale improvement.

Peru—Since 1983, CIMMYT has based a scientist in Peru in the capacity of co-leader of the National Cereals Program. Areas of research include 1) intensification of on-farm production agronomy research, 2) work on the main limiting factors of infertility and weeds, and 3) maintaining levels of acceptable disease resistance. Priority is also given to training. During the period 1983-86, approximately 20,000 lines of small grain cereals in different stages of development were evaluated. Two bread wheat varieties and one durum wheat variety were released for the Peruvian Sierra.

Turkey—CIMMYT has two programs in Turkey, the international winter wheat program discussed above and the bilateral program started in 1984 with UNDP funding. The two programs are closely aligned. However, activities specific to Turkey in the bilateral program include work to expand the development of winter bread and durum wheat germplasm and enhanced selection for types suited to marginal and rainfed conditions. Attention is also given to increasing wheat yields in areas that have lagged behind and developing materials for newly irrigated areas.

Economics Research

The work of the Economics Program is aimed at strengthening the capacity of national research programs to carry out efficient agricultural research. In 1986 there were 4 staff at headquarters and 12 involved in cooperative research and training activities in four regional programs (Central America and the Caribbean, Eastern and Southern Africa, South Asia, and Southeast Asia) and in two bilateral projects (Haiti and Mexico).

Economics staff have devoted much of their effort to the development and teaching of research procedures, primarily for conducting adaptive on-farm research. With these methods, which were developed in conjunction with CIMMYT agronomists and scientists in national programs, researchers assess the production circumstances and problems of the majority of farmers in target research areas, set priorities for experimental programs, and analyze experimental results. This approach to on-farm investigation is now being practiced in many production research programs in the Third World.

Members of one of Panama's regional on-farm research units conduct a formal survey of farmers as part of a call system course organized by the CIMMYT Economics Program.

Center economists are also developing methods for improving the efficiency of decision making in the allocation of resources within national programs. The aim of current efforts is to adapt the techniques of domestic-resource cost analysis to the problems of setting priorities. In other work we are examining the effects of the policy environment on the acceptability of technologies generated through on-farm research and developing methods through which researchers can deliver appropriate technical data to policy makers.

In addition, the Economics Program continues to work on the collection and analysis of data concerning the world maize and wheat economies. These analyses are useful both to national program decision makers and to CIMMYT staff.

Technology Generation

The Economics Program works with national programs in developing countries to formulate, demonstrate, and institutionalize on-farm research procedures. A growing number of national research institutes in Africa, Asia, and Latin America have integrated on-farm research procedures into the process of technology generation.

In 1986 Economics staff worked closely with scientists in selected countries where on-farm investigation has been institutionalized to further strengthen this type of research. Economics staff consulted with scientists in a number of other countries that already have well-established on-farm research efforts, including Indonesia, Pakistan, Zambia, Malawi, and Honduras. Our staff also demonstrated on-farm research techniques in other countries where scientists are considering how to adapt these procedures to their own institutional settings.

Training forms an important part of our work in on-farm research. Most of this training takes place in-country, and it is often conducted according to the "call system" approach, in which participants come together for periods of one to two weeks at key stages in the research cycle (for example, to conduct farm surveys, evaluate trial results, or plan subsequent experimentation). During 1986 call system courses were initiated in Haiti and Ethiopia. In addition, workshops on various social science components of on-farm research were offered in a number of countries.

Research Resource Allocation

The Economics Program is developing procedures for shaping research priorities and allocating resources within national research organizations. Our aim is to provide agricultural administrators with reliable means for making decisions about the distribution of scarce funds and trained personnel among competing crops and regions. Current work involves a series of case studies using the techniques of domestic-resource cost analysis to determine the profitability at the farm and national levels of alternative crops or production techniques.

Work continued in 1986 on case studies initiated previously, and a new study was begun in Zimbabwe to examine the likely costs of different options for increasing the country's wheat production. Drawing on experience gained from studies that have already been completed, we are planning a workshop on procedures for resource allocation.

Farm-Based Policy Research

The Economics Program is working on policy issues that affect the potential acceptability of technologies generated through adaptive research. In many instances the implementation of policies (on input delivery, marketing systems, credit, or extension) limits the diffusion of otherwise appropriate technology. These imperfections in agricultural policy can be attributed at least in part to a lack of technical information among policy makers. Using data generated by on-farm work, researchers should be able to supply administrators with information that will help them make more effective decisions on policy issues.

Economist Alberic Hibon (center) assists in the analysis of on-farm research data collected by Mexican scientists.

In 1986 case studies were completed that examined the consequences of and alternatives to policies affecting the availability of particular types of fertilizers in specific regions of Mexico and Haiti. Another study was carried out that considered the choice and distribution of types of wheat seed in Pakistan. Based on the experience gained in those studies, we are developing a framework within which scientists in national programs can apply data from on-farm research to the implementation of policy.

Data Collection and Analysis

The Economics Program collects and analyzes data on the production, utilization, and trade of maize and wheat. The results of these analyses are reported in alternate years in the series *World Wheat Facts and Trends* and *World Maize Facts and Trends*, which are aimed at agricultural administrators, researchers, and policy makers.

A study conducted in 1986 on the economics of maize seed production underscores the tremendous scope for wider dissemination of improved maize and calls attention to some of the circumstances that have limited its spread.

In 1986 an issue of *Maize Facts and Trends* was prepared that focuses on the vital issue of seed production in developing countries, in addition to providing basic information on the current situation of world maize production and utilization (see box). For the study of seed production, two sets of questionnaires were distributed. One went to CIMMYT outreach staff and their colleagues in national programs, who provided figures on the amount of maize seed planted, area sown to improved maize, and so forth for each of the major maize-producing countries of the world. The second questionnaire was sent to maize seed enterprises to collect data on costs, prices, yields, and other variables in seed production.

The Global Maize and Wheat Situation

Maize, with a global harvest of almost 480 million metric tons (Mt) in 1986, ranked with wheat and rice as the world's major cereal crops. Worldwide about two-thirds of all maize is used for feeding livestock, almost one quarter for human consumption, and about 10 percent for industrial purposes and seed. In 1986 developing countries produced 171 Mt of maize, roughly half of which was used for human consumption, slightly less than half for livestock feed, and the remainder for industrial purposes and seed. Maize is a particularly important part of the human diet in sub-Saharan Africa, Mexico, Central America and the Caribbean, and the Andean countries. During recent years growth in the demand for maize as a feed grain has slowed in the Third World because of economic downturns in many countries. In spite of those difficulties, however, developing countries imported some 22 Mt of maize during 1985-86 out of a total 55 Mt imported worldwide. Third World nations exported around 18 Mt, a large portion of which came from Argentina, China, and Thailand.

Worldwide production of wheat reached the record level of 534 Mt in 1986 (206 Mt of it in developing countries), having risen remarkably from 319 Mt in 1970. Roughly half of the increased production is grown in the Third World, where wheat consumption rose dramatically during the 1970s, driven by rapid population growth, urbanization, and rising incomes. During the 1980s the economic fortunes of many countries declined sharply, causing Third World wheat imports to level off in recent years. Even so, developing countries remain the largest wheat importing group, having received 54 Mt (including China) in 1985 out of the total shipments of 84 Mt.

The data and analysis presented underscore the tremendous scope for wider dissemination of improved maize and call attention to some of the circumstances that have limited its spread. That discussion, covering seed costs, pricing, and performance, is followed by a section on important issues that decision makers in developing countries must face as they try to promote the growth of effective seed industries. For example, what role does hybrid maize seed have to play, and what types of hybrids might be appropriate under prevailing circumstances in a given country's maize production? What place should the public and private sectors have in supplying improved seed to farmers? And what incentives are needed to encourage seed industries to do their jobs effectively? Decision makers should find much useful information in this study that will help them arrive at sound conclusions on those issues and others pertaining to the development of maize seed production.

Regional Programs

In each of our four regional programs, economists work with selected national programs in cooperative research projects and training activities. In eastern and southern Africa, we continue to emphasize the development of national capacities to conduct on-farm research, and the staff in that region devoted a very high proportion of their time to training activities in 1986. In Southeast Asia Economics Program activities included training and consulting with on-farm researchers. In South Asia emphasis was placed on applying on-farm research data to policy and planning issues in Pakistan. The regional staff in Central America and the Caribbean carried out several intensive training courses and developed case studies on farm-based policy research.

Staff of the Ghana Grains Development Project interviewing a farmer during a study on the adoption of technology recommended by the project.

Support Services

The research and training programs described in foregoing sections require support in field activities and laboratory analysis, and they generate tremendous amounts of data and information that must be presented in appropriate forms. Providing those services is the main responsibility of four research support units at Center headquarters in Mexico. CIMMYT staff are the direct recipients of many services they provide, but in numerous ways the activities of the support units reach beyond that group, affecting nearly all of our cooperators in developing countries.

Experiment Stations

In Mexico the primary responsibility of our experiment station management unit is to oversee field operations on some 500 hectares of land at various research stations and other experimental sites. The unit works closely with CIMMYT scientists and reduces their burden of day-to-day field supervision, so that they can concentrate on research issues. Experiment station staff attend to such matters as land preparation, fertilization, plant protection, irrigation, and management of field workers. Most of this work takes place at five stations in Mexico, four of which (El Batan, Poza Rica, Tlaltizapan, and Toluca) are managed directly by Center staff and the fifth (at Ciudad Obregon) by the National Institute for Agricultural, Livestock, and Forestry Research (INIFAP).

In addition, the unit offers an in-service training course, in which station workers from developing countries spend about five months in Mexico studying and gaining experience in the whole range of activities that are involved in running an experiment station. In the past this course has been offered twice a year, but starting in 1987, it will be conducted once annually for larger groups of participants.

This step and the return of one staff member upon completion of his graduate studies have permitted experiment station management staff to begin committing a much larger share of their time to support of station work in countries other than Mexico. During 1986 three staff members devoted approximately six man-months to visits in Bolivia, Kenya, Nicaragua, Panama, Paraguay, Peru, Thailand, and Turkey. Their purpose in making such trips (which are organized by regional specialists in the Maize and Wheat Programs at the request of national staff) is to offer assistance in the development and improvement of experiment station facilities and to conduct courses on specific topics that cannot be covered by the more general in-service course given at headquarters. The unit has been involved in 64 separate experiment station projects in the Third World (of which 18 are ongoing), an obvious indication that there is a large demand for this service.

Laboratories

Most of the thousands of analyses conducted by laboratory staff are used by CIMMYT researchers in crop improvement work at headquarters and in outreach programs. This information provides valuable guidance in selecting materials for certain desirable traits that cannot readily be measured in the field.

Overseeing field operations is a major responsibility of Experiment Station staff, who in doing so free CIMMYT scientists to concentrate on research.

Some 20,000 samples of quality protein maize (QPM) germplasm, for example, are analyzed each year to detect any negative changes in protein status that may take place as the materials are selected for yield, kernel modification, and other traits. The laboratory also conducts protein fractionation periodically in advanced QPM populations to determine the effects of genetic modifiers that have been accumulated in these materials on their protein balance. In addition to handling the routine work of QPM analysis, laboratory staff conducted and published during 1986 a study on the stability of improved protein quality in typical maize products such as tortillas. They also trained five researchers from five countries in procedures for quality protein analysis.

In a parallel activity, the Wheat Program's milling and baking laboratory conducted extensive evaluations of early generation lines for good grain type and other characteristics (including protein and pigment content) and of advanced lines for traits such as test weight and milling and baking qualities. Maintenance of high standards in those characteristics is essential to the ultimate acceptability of wheat lines disseminated by CIMMYT to breeders in developing countries.

Another activity that laboratory staff are engaged in primarily for the Wheat Program is screening of germplásm for tolerance to aluminum toxicity. Wheat scientists have a longstanding project for development of this trait in cooperation with Brazilian scientists and routinely request the services of laboratory staff in their aluminum tolerance work. The Maize Program, on the other hand, has just recently initiated an international program in the Andean region for developing germplasm that is tolerant to aluminum toxicity.

One service provided regularly by laboratory staff across programs is the analysis of soil and plant tissue samples. Many requests for this type of analysis come from participants in training courses at headquarters, who use the results in planning experiments. A particularly large influx of soil and tissue samples came from the Maize Program's physiology unit this year as part of its work on drought tolerance and nitrogen-use efficiency.

Information Services

A number of important changes occurred during 1986 within Information Services. The unit came under new direction at the beginning of the year, and several other key staff were hired; the group moved into new facilities (the Norman Borlaug Building); and the unit adopted new word processing and library automation hardware and software. All these changes reflect a continuing commitment by CIMMYT management to meet in an efficient manner the information needs of the Center's various clients.

Experiment Station staff have assisted in 64 separate projects for station development in the Third World, an obvious indication that there is a large demand for this service.

The primary objectives of the Information Services unit remain unchanged, however. They are to assist Center staff 1) in communicating the results of their research to colleagues around the world, 2) in remaining current in their respective fields by providing better access to the results of research done elsewhere, and 3) in improving the effectiveness of maize, wheat, and economics training activities. The group is thus organized into three interrelated areas: publications production, a scientific information unit (which includes our specialized library and is currently funded by Canada's International Development Research Centre, IDRC), and training materials/audiovisuals development.

In publications a senior science writer/editor and an associate English language editor joined the staff during the year; a second associate editor (Spanish) was identified and will join the group in January 1987. Some 60 new publications of various types were produced (Appendix V), with emphasis given to practical guidebooks intended to enhance the competencies of national program staff and widen their access to CIMMYT germplasm and information. An increasing number of those titles were translated into other languages (primarily Spanish and French), a trend we anticipate will continue. Distribution of the Center's publications expanded rapidly through the use of an increasingly well targetted mailing list system containing names and addresses of over 7600 individuals, libraries, and national program institutions.

Our scientific information unit (SIU)/library also underwent important staffing changes with the hiring of a professional information officer (to assist Center staff in information database searches) and a professional librarian (whose immediate challenge is one of streamlining and automating our traditional library services). Further details on the work of the SIU are given in the section of this report that covers extra-core grants.

Another significant staffing decision occurred with the identification of an associate training materials/audiovisual coordinator, who will join the information group in January 1987. This decision reflects a renewed commitment to the development of training materials, as well as a recognition of the need to develop materials that take full advantage of cost-effective instructional A/V technologies. Priority activities will include reorganization of photographic services, design and implementation of an ''image bank'' for color slides and black and white negatives, and the clear delineation of a training materials agenda that reflects the needs of CIMMYT training officers and trainees.

Data Processing

This unit provides vital support in every aspect of CIMMYT's operations (research, administration, information services, accounting, personnel management, and so forth) by assisting in statistical analysis, developing new software, installing and maintaining hardware, and assisting computer users. The addition of staff and some accompanying reorganization in 1986 enabled Data Processing to make an unprecedented contribution to the computerization of Center activities that previously were done by hand or according to older, less efficient systems; some were not done at all for lack of resources.

The most important change in organization was the creation of an operations unit responsible for hardware and of a software development unit. Under the latter, programmers that previously worked within the two crop programs were consolidated to form a single crop systems development group consisting of five staff. Three new programmers were added to the software unit (through special funding from Digital Equipment Corporation, IDRC, and the government of Denmark), bringing its total number up to 10. The operations unit acquired one additional staff member to organize training and provide assistance to computer users.

The major acquisitions of the operations group this year were several microVAX computers (one for software development, another for the Wheat Program, and a third, donated by the government of West Germany, that will serve various units) and 40 IBM personal computers, plus eight more given to us by IBM, Mexico. One of the unit's main accomplishments in 1986 was to install the PCs, which are being used mainly for word processing, spread sheet analysis, and experiment station operations. This group also began setting up a local area network that, when complete, will allow us to connect a larger number of terminals at lower cost, among other advantages.

In software development, several important projects were brought to completion, and others were carried through important design and testing stages. Among the items of software finished was a pedigree management system for the Wheat Program. This system serves as the basis for other software, including an international nursery system and breeders' seed inventory system, both completed in 1986, and a wheat field book system, for which we have just completed an assessment of the Program's requirements. Separate nursery mailing list systems were developed for the Wheat and Maize Programs along with other software that is enabling the maize germplasm bank to compile information on landraces and other accessions in a computer database. In addition, a database from the Food and Agriculture Organization (FAO) that contains crop production and related information was updated and made available to users, particularly in the Economics Program.

Extra-Core Grants

Extra-core programs are undertaken within a direct relationship between CIMMYT and a donor. Although they fall outside of the Center's core program (sponsored by the CGIAR), they form an important part of its research and training efforts. Extra-core programs are generally of four types:

- Direct assistance (posting of staff or provision of research equipment) to national or regional programs
- Specialized or advanced-degree training
- Cooperative research arrangements of a more basic or long-term nature
- Special exploratory research activities

The CIMMYT Board of Trustees has established the following guidelines for judging the relative merit of projects funded through extra-core grants:

- The action should not be a mere technical assistance contribution to a country or region, but have some potential for strengthening the Center's overall research competence and adding to the base of scientific knowledge.
- The project should have, wherever appropriate, a training component that enables CIMMYT staff to gain experience or enhances national capacity in the area of concern.
- Any administrative costs to the Center should be fully identified and reimbursed by overhead or other means in the funding of the project.
- There should be no implied continuing obligation on the part of CIMMYT; that is, all potential costs for staff repatriation and rehabilitation and ancillary costs on termination must be covered by the donor.

In 1986 extra-core grants amounted to US$6,436,000 or 23 percent of total expenditures. Reports on major grants are given in the following pages. Several of those provide funds for posting staff in national research programs, and all contribute in important ways to the Center's research programs.

The recently completed Norman E. Borlaug Training, Conference, and Information Center.

Capital Improvements

Project:	**Training, Conference, and Information Center**
Donor:	Japan Shipbuilding Industry Foundation and Government of Japan
Pledge:	US$ 1,000,000 US$ 586,274
Other Revenue:	Interest earned on advance payment of donation US $144,000
Duration:	January 1985 to September 1986
Financial Summary	Expenses (US$): Previous years $ 903,000 1986 $ 827,000 Total to date $ 1,730,000 Balance available -0-

Objectives—This project funded the construction of the Norman E. Borlaug Building at CIMMYT headquarters, which is permitting a sizeable expansion of services in training and information as well as accommodating growth in the crop programs.

Activities in 1986—By the end of the year, construction had been completed, and staff of the maize and wheat training programs, publications unit, scientific information unit (SIU)/library, and Wheat Program had moved into their new quarters. The basement of the building, which has three floors, is occupied by the publications unit and the SIU/library. Those units are now well situated for increasing their efforts in the production and distribution of printed and audiovisual information products and in the use of major bibliographic databases. Another important means of information exchange will be aided by the seminar facility on the main floor, which is equipped with modern systems for simultaneous translation and audiovisual presentations. This floor also houses the training programs, which now have ample space for the classroom portion of in-service courses, access to a combination self-learning center/language laboratory and microcomputer users room (both part of the library), and office space for 10 visiting scientists on the second floor. Other offices on that floor are now used by several Wheat Program staff.

Maize

Project:	**Central America and Caribbean Maize Seed Production**
Donor:	Swiss Development Cooperation
Pledge:	US$ 1,050,000
Duration:	July 1983 to December 1986
Financial Summary	Expenses (US$): Previous years $ 366,000 1986 $ 577,000 Total to date $ 943,000 Balance available $ 107,000

Objectives—This project was established to improve maize seed production in 13 countries of the Central America and Caribbean region. Although seed industries have expanded considerably in the region over the past few years (particularly in El Salvador, Guatemala, and Nicaragua), growth has been slow in some countries, and in general weak seed production operations have been an impediment to the spread of new germplasm developed by national maize programs. In their breeding and agronomy research, those programs are assisted by a companion project that is also funded by the Swiss Development Cooperation, but as part of CIMMYT's core program.

Activities in 1986—The current work of this project (staffed by one maize scientist based in Guatemala) is to help countries in the region develop effective seed production strategies. The most promising approach is based on a strategy already adopted with some success in Guatemala and that, with appropriate modifications, should prove to be effective in other countries as well. Two important elements of that strategy are production of basic seed by the national maize program and of foundation seed by a unit set up specifically for that purpose. Much of the project's resources was committed to developing and supporting such units during 1986.

Maize

Project:	**East Africa Cereals Program**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 1,760,000 US$ 1,354,000 (est.)
Duration:	October 1984 to June 1988
Financial Summary	Expenses (US$): Previous years $ 227,000 1986 $ 420,000 Total to date $ 647,000 Balance available $ 707,000

Objectives—The principal aim of this project is to strengthen the maize agronomy research capacity of seven nations in the region: Burundi, Ethiopia, Kenya, Rwanda, Somalia, Tanzania, and Uganda. Although project staff are currently working with those countries individually, they also try to support regional initiatives by participating in workshops organized biennially by CIMMYT's regional maize program. The primary services offered by the project are consultation and in-country training; the latter is often conducted in cooperation with Economics Program staff and with other development organizations operating in the region. In a companion project, funded by CIDA from the same grant, the Wheat Program is working toward essentially the same objectives in agronomy research on small grains.

Activities in 1986—The two agronomists staffing this project (which has its headquarters at Nairobi) visited all seven countries several times in 1986 and now have a fairly clear idea of the region's agronomy research history, needs, and opportunities. During those visits their time was divided between consultation (mainly for identification of problems and planning of agronomic experiments) and training and other types of assistance in on-farm research (OFR). Much of the OFR work is organized jointly with the Economics Program, as in the case of call system courses and another type of event that has been dubbed the *networkshop*. In the latter (one of which was held in Ethiopia this year) researchers from throughout the region visit one country to review its OFR program and share their own insights and experiences.

Maize

Project:	**Ghana Maize Program, Phase II**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 4,977,866 US$ 3,750,000
Duration:	October 1983 to March 1989
Financial Summary	Expenses (US$): Previous years $ 1,519,000 1986 $ 726,000 Total to date $ 2,245,000 Balance available $ 1,505,000

Objectives—The objective of this project, which was initiated in 1979 and is now in its second phase, is to improve maize and grain legume production in Ghana through improved technologies and to strengthen the overall research capacity of the country's Crops Research Institute. The CIMMYT Maize Program provides a resident joint project coordinator and agronomist, and Economics Program staff make periodic visits to assist with on-farm research. The International Institute of Tropical Agriculture (IITA) coordinates the research on grain legumes.

Activities in 1986—Work continued this year on improvement of maize pools and populations, and numerous national and international maize and cowpea trials were carried out. Project agronomists were active in conducting investigations on weed control, integrated pest management, intercropping, and other problems. With assistance from the CIMMYT Economics Program, project economists and other staff made an informal survey of 180 farmers in an area where extensive on-farm research has been conducted. The results indicated a fairly high rate of adoption by farmers of project technologies and recommendations, which were developed and tested in hundreds of trials at locations throughout the country. To strengthen these research efforts, the project has a large training component that includes various types of in-country courses and workshops as well as graduate studies. Three national staff completed master's and Ph.D. programs, and a number of others continued or began study programs.

Maize

Project:	**Pakistan Maize Program**
Donor:	United States Agency for International Development (USAID)
Pledge:	Rps 9,026,879 (US$ 524,000) US$ 740,000
Duration:	October 1984 to September 1987
Financial Summary	Expenses (US$): Previous years $ 505,000 1986 $ 229,000 Total to date $ 734,000 Balance available $ 530,000

Objectives—The maize portion of this project, which also includes wheat and economics components, was set up to assist the Pakistan Agricultural Research Council in its work with provincial research institutes. The central purpose of that work is to increase the availability of improved maize technology to farmers, with the aim of boosting production to meet growing demand for maize in the poultry industry.

Activities in 1986—The project's primary means of achieving those objectives are assistance to the national breeding effort and participation in a stepped-up on-farm research program initiated during 1984. In germplasm work the CIMMYT scientist staffing this project worked with national and provincial scientists in developing and improving early maturing maize for upland areas and winter/spring plantings. The project was also actively involved in a multidisciplinary on-farm research program that is working toward a clearer understanding of farm-level constraints of maize production, identifying technical solutions, and testing and demonstrating those solutions in farmers' fields. In addition, the project scientist is consulting with a program for development of modified maize planting and shelling equipment that is now being manufactured locally and should help farmers save considerable time and labor.

Wheat

Project:	**Barley Yellow Dwarf Virus (BYDV)**
Donor:	Italy
Pledge:	US$ 1,477,017
Duration:	January 1984 to December 1987
Financial Summary	Expenses (US$): Previous years $ 193,000 1986 $ 425,000 Total to date $ 618,000 Balance available $ 859,017

Objectives—The project aims to reduce losses caused by this virus by supporting the transfer of technology currently available in developed country institutions to Third World countries via CIMMYT. Since BYDV is both significant and ubiquitous, the development of resistant germplasm could increase cereal production in developing and developed countries by decreasing the losses it currently causes. The project's overall goal is to identify sources of resistance to the virus from research currently being undertaken in several institutions and transfer this technology through a cooperative network to institutions throughout the world, especially in developing countries.

Activities in 1986—Seven main aphid species that feed on small grains have been identified in Mexico. Work to date also indicates that there are three main isolates of the virus present in Mexico. At CIMMYT the ELISA facility, purchased with Italian funds, has become functional and uses antisera purchased from institutions in England. With ELISA, the Center can now test dried leaf samples thought to be infected with BYDV. ELISA is also being used to examine the virus concentration in BYDV-resistant plants to see if this technique may be used as an adjunct to symptom assessment for selecting resistant plants. Construction of an aphid rearing and handling facility within the greenhouse complex began in 1986, and it will be operational by 1987.

Wheat

Project:	**Introduction of Alien Genes into Wheat Through Conventional and Biotechnology Approaches**
Donor:	Australia
Pledge:	A $ 140,000 US$ 114,000
Duration:	Australia, multiyear; UNDP, negotiated annually
Financial Summary	Expenses (US$): Previous years $ 15,000 1986 $ 74,000 Total to date $ 89,000 Balance available $ 25,000

Objectives—The objectives of the wheat wide cross program are to incorporate resistance to *Helminthosporium sativum*, *Fusarium graminearum*, and *Tilletia indica* (Karnal bunt) and stress tolerance (salt, drought, heat, aluminum, and copper) from related genera into wheat.

Activities in 1986—Interspecific hybridization, a new area of investigation, was initiated in February during the Ciudad Obregon crop cycle. The objectives are similar to those of the ongoing intergeneric hybridization program. The species involved are more closely related to wheat and in 1986 included *Triticum urartu*, *T. boeticum*, *T. araraticum*, *T. dicoccoides*, *T. dicoccum*, *T. tauschii*, and *T. carthlicum*. Interspecific efforts, due to the existence of close phylogenetic relationships, ease of crossability, and opportunities for high recombination status, offer wheat programs short-term payoffs (7 to 10 years).

Wheat

Project:	**East Africa Cereals Program**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 993,000 US$ 764,000 (est.)
Duration:	October 1984 to June 1988
Financial Summary	Expenses (US$): Previous years $ 182,000 1986 $ 166,000 Total to date $ 348,000 Balance available $ 416,000

Objectives—The project has as its principal objective increased wheat and triticale productivity in Burundi, Ethiopia, Kenya, Rwanda, Somalia, Tanzania, and Uganda. The project seeks to transfer improved wheat production technology to the countries of eastern Africa, primarily through improved agronomic practices and varietal improvement.

Activities in 1986—The project agronomist concentrated his time in Ethiopia and Kenya, where more than 90 percent of the region's small grains are produced. Single visits were made to most of the other countries in the region. During monthly visits to Ethiopia, the agronomist was involved in planning trials on rotation, fertility, use of grain and forage legumes to break up continuous wheat cultivation, tillage, use of rock phosphate and bone meal, seeding rates, herbicides, and irrigation frequency.

In Kenya weed control and fertility maintenance continued to be areas of the utmost importance. Most of the CIMMYT agronomist's time in Kenya was spent in the areas of acid soils, marginal rainfall, high-altitude barley, and mid- to high-altitude wheat. The project agronomist also participated in a number of workshops, in-country training sessions, and field days throughout the region.

Wheat

Project:	**Bangladesh Wheat Program**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 4,680,000 US$ 3,744,000 (est.)
Duration:	April 1982 to April 1987

Financial Summary

Expenses (US$):	
Previous years	$ 1,595,000
1986	$ 586,000
Total to date	$ 2,181,000
Balance available	$ 1,563,000

Objectives—The overall objectives of the project are to increase wheat production in Bangladesh by developing superior wheat varieties and improved production technologies, and to help strengthen and support the research and production staff currently assigned to the wheat research program of the Bangladesh Agricultural Research Institute.

Activities in 1986—BAW 38, introduced as an advanced line from Pakistan in 1979, was released under the varietal name, Agrahni, in October. Agrahni is expected to compete extremely well against leaf rust-susceptible Sonalika, the predominant commercial variety, particularly at late dates of planting.

There is general agreement that wheat stands in Bangladesh are poor relative to those expected under the best growing conditions because of a steady loss of micronutrients with increased intensification of cropping. Wide-ranging soil analyses tend to confirm this, with data indicating several areas deficient in boron and manganese. A soil chemist specializing in micronutrients will arrive for a month's stay in January 1987 to further investigate this situation.

Approximately 600 farmers at respective district headquarters attended lectures and demonstrations on proper seed placement and plant establishment. Groups of farmers also participated in traveling seminars at two regional research stations. These seminars, now in their third year, have been very successful in showing farmers the performance of newly developed varieties in the field.

Wheat

Project:	**Pakistan Wheat Program**
Donor:	United States Agency for International Development (USAID)
Pledge:	Rps 12,817,176 (US$ 1,744,000) US$ 1,078,750 (est.)
Duration:	October 1984 to September 1987

Financial Summary

Expenses (US$):	
Previous years	$ 454,000
1986	$ 431,000
Total to date	$ 885,000
Balance available	$ 938,000

Objectives—This project, in which the Maize and Economics Programs also participate, is a continuation of an association with USAID and the Pakistan Agricultural Research Council. The overall objective is to develop improved varieties and agricultural technologies for the increased production of wheat and maize in Pakistan.

Activities in 1986—In addition to the many provincial screening and yield nurseries, 250 national uniform yield trials were sent throughout Pakistan. Several lines showed wide adaptability across regions and had good disease resistance. Seventy-nine CIMMYT nurseries and 70 from the International Center for Agricultural Research in the Dry Areas (ICARDA) were distributed to provincial wheat programs through the wheat coordinator. Results were compiled and sent back to the respective international centers.

The CIMMYT on-farm specialist assisted in a survey of farmers' knowledge and perceptions of wheat technology in the rice-wheat, cotton-wheat, and maize-wheat zones. The results showed that farmers are not getting the improved, disease-resistant wheat seed fast enough. More than 50 percent of each zone is still sown to disease-susceptible varieties. Much more work is needed to determine if the problem is seed multiplication, distribution, or knowledge of the farmer.

Wheat

Project:	**Peru National Cereals Program**
Donor:	Peruvian National Institute for Agricultural Research and Production (INIPA) and World Bank
Pledge:	US$ 482,000
Duration:	August 1983 to December 1987
Financial Summary	Expenses (US$): Previous years $ 303,000 1986 $ 91,000 Total to date $ 394,000 Balance available $ 88,000

Objectives—The project is designed to help INIPA strengthen its cereals research program through: 1) consulting with national cereals research coordinators in program planning and research implementation, including the development of research facilities and manpower, and 2) assisting program leaders to develop a national in-service training program and participating in the selection of candidates for advanced training outside Peru.

Activities in 1986—Germplasm development and improvement continued during 1986. Since the project's initiation in 1983, the National Cereals Program has evaluated approximately 20,000 lines of small grain cereals in different stages of development, including locally derived materials from abroad, principally from CIMMYT and ICARDA. Three wheat varieties for the Sierra have been released.

Because of funding problems with the project, in-service training in Mexico was funded entirely by CIMMYT in 1986. An INIPA extension agent from the Majes Valley made a short visit to study irrigation and soil management at seeding time in the Yaqui Valley of northern Mexico.

In March a regional cereal researchers workshop was held in Peru. Participants came from all four small grain cereal-producing countries of the Andean Region and the CIMMYT base program. Emphasis was on informal discussions and interchange of ideas among the participants.

Wheat

Project:	**Wheat Improvement in Turkey**
Donor:	United Nations Development Programme (UNDP)
Pledge:	US$ 391,000
Duration:	December 1983 to December 1986
Financial Summary	Expenses (US$): Previous years $ 241,000 1986 $ 150,000 Total to date $ 391,000 Balance available -0-

Objectives—The project seeks to strengthen small grains cereals research in Turkey by: 1) establishing a germplasm exchange and distribution system that will allow Turkey to benefit from improved germplasm with superior characteristics, 2) developing improved varieties that are suitable for particular wheat-growing zones in Turkey, 3) increasing understanding of the role and control of small grain diseases in production, and 4) initiating a national in-service training program to ensure the long-term sustainability of the national cereals research program.

Activities in 1986—In April a one-year extension of the project was approved, so work continued toward meeting the above objectives. Between 1500 and 2000 crosses (mainly winter x winter) per crop cycle are presently made at Ankara, Edirne, and Eskisehir. This variability is employed in the international winter wheat program as well as the national program. A program has been initiated at Izmir to place more emphasis on exploiting winter x spring wheat crosses. The 2nd International Winter Wheat Screening Nursery (IWWSN) was prepared during the summer, consisting of 103 entries. Sets were sent to 50 locations throughout the winter wheat regions of the world. Candidates were identified for the 3rd IWWSN and were planted in Edirne for multiplication.

Economics

Project:	**On-Farm Research in Eastern and Southern Africa**
Donor:	United States Agency for International Development (USAID)
Pledge:	US $ 5,000,000
Duration:	January 1986 to May 1990
Financial Summary	Expenses (US$): Previous years -0- 1986 $ 691,000 Total to date $ 691,000 Balance available $ 4,309,000

Objectives—This project, which entered its second phase at the beginning of 1986, is providing assistance in on-farm research (OFR) to a number of national agricultural research and extension institutions and USAID agricultural project management teams in eastern and southern Africa. Another economist joined the project this year, bringing the total number of staff up to three, with one based at Nairobi, another at Harare, and the new project staff member at Lilongwe in Malawi.

Activities in 1986—Most of the project's resources go into training, workshops, and consultation aimed at establishing and maintaining national OFR efforts. This year various stages were completed in call system courses taking place in Ethiopia and Kenya, and other types of training courses or workshops were held in a number of countries. Partly as a result of those types of activities, most countries in the region are actively engaged in OFR. It became particularly apparent this year that those programs now require more training and assistance in analyzing trial data and in developing future plans on the basis of trial results. For that reason many of the training events and much of the consultation provided by project staff in 1986 centered on statistical and economic analysis.

The development of OFR programs also places heavier demands on researchers and administrators in the coordination and integration of that work into other research activities. To assist with those efforts, project staff took part in planning sessions in several countries of the region.

Economics

Project:	**Haiti Economics Program, Phase II**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 778,395 US$ 564,000 (est.)
Duration:	January 1985 to December 1988
Financial Summary	Expenses (US$): Previous years $ 85,000 1986 $ 178,000 Total to date $ 263,000 Balance available $ 301,000

Objectives—The primary aim of this project is to assist Haitian researchers in the development and diffusion of improved technologies that are appropriate to the biological and socioeconomic circumstances of the country's maize farmers. The CIMMYT economist responsible for this work is assisted (at no cost to the project) by a Center maize agronomist and an economist assigned to the Central America and Caribbean regional program, which is a core-restricted effort funded by the Swiss Development Cooperation.

Activities in 1986—One of the most important tools employed to accomplish the project's objectives is OFR. This year a call-system course on OFR was initiated for researchers from all over Haiti, and project staff continued to participate in an OFR project in Les Cayes, southwestern Haiti. They also completed an analysis of fertilizer policy at the farm level, a project in which data generated through OFR are being used to identify adjustments in policy that might lead to more appropriate distribution of fertilizer.

Economics

Project:	**Pakistan Economics Program**
Donor:	United States Agency for International Development (USAID)
Pledge:	Rps 2,689,050 (US$ 156,000 est.) US$ 300,000
Duration:	October 1984 to September 1987
Financial Summary	Expenses (US$): Previous years $ 75,000 1986 $ 53,000 Total to date $ 128,000 Balance available $ 328,000

Objectives—All three of CIMMYT's main programs participate in this project, which grew out of previous work by USAID and the Pakistan Agricultural Research Council. The economics component of the project was established in 1984 and is staffed by one economist. He receives assistance from CIMMYT's regional economist in South Asia, who is also stationed in Pakistan and devotes about 50 percent of his time to the work there, using core funding. The purpose of the economics research, like that of the maize and wheat components, is to make improved agricultural technology more widely available to farmers.

Activities in 1986—Project staff conducted surveys to gather information about farmers' use, knowledge, and perception of improved wheat technologies, such as new varieties, weed control measures, and fertilization practices. A paper reporting the results of surveys on maize production in the Northwest Frontier Province was published this year. It points to a number of issues that influence farmers' acceptance of improved maize technologies. Among those are various socioeconomic circumstances, such as the form of land tenancy and the sharing of inputs, grain, and fodder under that arrangement, and the extremely complex matter of farmers' dual use of maize as a grain and fodder crop. Information about those issues should provide valuable guidance in future planning of research and extension for the province. There and elsewhere in the country a multidisciplinary on-farm research program is further exploring the types of issues raised in the study.

Information Services

Project:	**Information Service for Wheat and Other Small Grains**
Donor:	International Development Research Centre (IDRC), Canada
Pledge:	CA$ 387,075 US$ 295,000 (est.)
Duration:	June 1984 to June 1987
Financial Summary	Expenses (US$): Previous years $ 97,000 1986 $ 59,000 Total to date $ 156,000 Balance available $ 139,000

Objectives—The purpose of this project is to provide information and documentation services for researchers working on wheat and other small grains. With the addition of one new position this year (as supervisor of information services), the project now has a staff of five.

Activites in 1986—Most of their efforts are directed toward providing three main services: 1) database searches, 2) document delivery based on a coupon system, and 3) distribution of various bibliographic materials. During 1986 the number of database searches done for CIMMYT staff tripled to over 400, while our fledgling document delivery service grew rapidly, nearing the 3000 mark in number of documents delivered. Copublication with the Commonwealth Agricultural Bureaux (CAB) of the *Wheat, Barley, and Triticale Abstracts* and *Maize Abstracts* continued, while the 1986 issues of the CIMMYT/AGRIS *Wheat, Barley, and Triticale Bibliography* were delayed until early 1987, pending system changes within AGRIS.

Another element of the project consists of state-of-the-art reviews on topics closely related to the Center's research. As part of the first review, initiated in 1985, seven Regional Disease Trap Nurseries and two International Disease Trap Nurseries were analyzed and the results submitted to CIMMYT.

The SIU also undertook preliminary testing of CD-ROM technology for CAB International, becoming one of 40 test sites located in 26 countries. Results of this effort will become available in early 1987.

Appendix I

Distribution of Maize Program international trials, 1985-86

	IPTT[a]		EVT/ELVT[b]	
	1985	1986	1985	1986
Mexico, Central America, and Caribbean	**33**	**21**	**159**	**37**
Belize	—	—	—	3
Costa Rica	3	3	8	—
Cuba	1	—	8	2
The Dominican Republic	2	—	6	—
El Salvador	—	3	3	—
Grenada	—	—	1	2
Guatemala	3	1	3	—
Haiti	—	—	—	4
Honduras	2	—	12	—
Jamaica	—	—	12	—
Mexico	17	14	60	9
Nicaragua	2	—	10	—
Panama	3	—	28	15
St. Kitts	—	—	6	2
Trinidad	—	—	2	—
South America	**25**	**19**	**113**	**67**
Argentina	—	1	23	6
Bolivia	5	6	22	21
Brazil	6	7	12	15
Chile	1	—	2	3
Colombia	6	1	1	2
Ecuador	2	—	3	2
Paraguay	—	1	5	2
Peru	4	1	25	9
Surinam	—	—	2	1
Uruguay	—	—	3	2
Venezuela	1	2	15	4
Middle East/North Africa	**4**	**4**	**44**	**17**
Egypt	2	2	7	—
Iran	—	—	4	—
Jordan	—	—	6	9
Libya	—	—	3	2
Mauritania	—	—	4	—
Morocco	—	1	6	5
Qatar	—	—	2	1
Saudi Arabia	—	—	2	—
Turkey	2	1	2	—
Yemen, North	—	—	8	—
Sub-Saharan Africa	**17**	**9**	**199**	**131**
Angola	—	—	6	—
Burkina Faso	2	1	20	2
Burundi	—	—	9	—
Cameroon	1	—	7	—
Cape Verde	—	—	3	—
Congo	—	—	—	2
Ethiopia	—	2	12	8
Gabon	—	—	1	—
Gambia	—	—	5	—
Ghana	—	—	3	—
Sub-Saharan Africa (continued)				
Guinea-Bissau	1	1	—	—
Ivory Coast	1	—	—	—
Kenya	2	—	26	4
Liberia	—	—	—	6
Madagascar	—	—	3	5
Malawi	1	1	—	11
Mali	—	—	6	—
Mauritius	—	—	1	—
Mozambique	—	—	5	—
Nigeria	2	1	—	6
Reunion	—	—	8	—
Senegal	—	2	24	23
Sierra Leone	—	—	6	—
Somalia	—	—	3	—
South Africa	—	—	—	4
Sudan	1	—	8	3
Swaziland	—	—	8	5
Tanzania	—	—	7	5
Togo	—	—	—	8
Uganda	—	—	6	3
Zaire	4	—	—	13
Zambia	—	—	6	12
Zimbabwe	2	1	16	11
Asia	**20**	**19**	**202**	**243**
Bangladesh	1	—	3	17
Burma	—	—	14	24
China	1	1	26	6
India	2	7	3	6
Indonesia	2	—	12	5
Korea, South	—	—	2	1
Laos	—	—	4	—
Nepal	3	—	7	7
Pakistan	3	4	11	20
The Philippines	—	3	50	41
Sri Lanka	—	—	7	—
Taiwan	—	—	—	17
Thailand	5	4	49	53
Vietnam	3	—	14	46
Other	—	—	**15**	**4**
France	—	—	9	2
Greece	—	—	2	2
Spain	—	—	1	—
USA	—	—	3	—
Total trials	**99**	**72**	**732**	**499**
Total countries	**35**	**26**	**75**	**54**

a International Progeny Testing Trial.
b Experimental Variety Trial and Elite Variety Trial.

Appendix II

Distribution of Wheat Program international nurseries, 1986

	Bread Wheat	Durum	Triticale	Barley	Germ. Dev.	Special Nur.
Latin America	**348**	**81**	**83**	**25**	**23**	**90**
Argentina	65	18	4	2	3	10
Bolivia	25	11	5	—	—	3
Brazil	72	4	20	6	6	32
Chile	24	20	10	—	—	13
Colombia	15	3	5	—	—	3
Costa Rica	9	1	1	—	—	1
Ecuador	11	—	4	1	2	5
Guatemala	10	—	3	2	—	1
Mexico	41	10	18	8	6	11
Paraguay	36	—	—	4	2	4
Peru	26	14	10	—	3	6
Uruguay	8	—	2	2	1	1
Venezuela	6	—	1	—	—	—
Africa	**268**	**104**	**74**	**64**	**29**	**103**
Algeria	9	2	3	3	—	4
Angola	1	1	1	1	—	1
Burkina Faso	—	—	—	—	—	1
Cameroon	5	1	1	2	1	2
Congo	4	—	—	—	—	—
Egypt	21	14	8	—	4	6
Ethiopia	12	9	2	2	2	6
Gabon	—	—	—	1	—	—
Kenya	26	10	5	5	4	11
Libya	12	15	5	13	1	6
Malawi	8	—	2	1	2	2
Mali	7	5	2	—	—	2
Morocco	10	11	5	5	1	8
Mozambique	9	4	4	2	—	2
Nigeria	10	—	1	2	—	2
Rwanda	14	—	5	2	2	4
Senegal	—	—	—	—	—	1
Somalia	—	—	—	—	—	1
South Africa	23	10	9	7	6	7
Sudan	9	—	—	—	—	3
Swaziland	—	—	—	—	—	1
Tanzania	14	3	3	8	1	6
Tunisia	15	16	7	7	—	12
Uganda	5	1	2	—	1	3
Zaire	21	—	4	—	1	2
Zambia	27	1	3	1	1	4
Zimbabwe	6	1	2	2	2	6
Middle East	**116**	**96**	**35**	**44**	**20**	**55**
Cyprus	2	4	—	2	—	2
Iran	4	—	1	3	1	4
Iraq	1	—	1	2	—	2
Israel	18	6	3	—	7	3
Jordan	13	18	6	5	2	6
Lebanon	1	4	—	2	—	2
Qatar	3	—	—	2	—	—
Saudi Arabia	4	2	1	1	—	3
Syria	18	22	6	11	4	14
Turkey	41	33	14	16	4	15
Yemen, North	8	7	3	—	2	2
Yemen, South	3	—	—	—	—	2

	Bread Wheat	Durum	Triticale	Barley	Germ. Dev.	Special Nur.
Asia	**311**	**57**	**55**	**50**	**25**	**88**
Afghanistan	6	6	3	4	2	6
Bangladesh	34	1	1	—	1	5
Bhutan	6	1	2	1	—	2
Burma	10	—	—	1	2	2
China	100	19	20	22	11	37
India	29	16	2	—	2	7
Indonesia	11	2	2	—	—	1
Japan	3	—	1	1	—	—
Korea, North	5	1	1	1	—	—
Korea, South	3	1	2	3	—	1
Nepal	19	1	1	1	1	5
Pakistan	36	5	8	12	4	15
The Philippines	19	—	3	—	—	3
Sri Lanka	—	—	—	—	—	1
Taiwan	2	—	—	1	1	—
Thailand	27	4	9	2	1	3
Vietnam	1	—	—	1	—	—
Oceania	**33**	**9**	**11**	**7**	**2**	**16**
Australia	25	2	6	4	2	6
New Zealand	8	7	5	3	—	10
New Caledonia	—	—	1	1	—	—
Europe	**124**	**105**	**114**	**51**	**21**	**68**
Albania	4	7	5	3	—	1
Austria	—	5	1	1	1	1
Belgium	1	—	1	—	—	—
Bulgaria	—	7	2	—	4	5
Czechoslovakia	3	—	2	3	2	2
England	5	1	5	2	—	2
Finland	1	—	3	1	—	—
France	14	8	13	2	3	5
Germany, East	3	—	3	3	1	1
Germany, West	1	11	7	2	—	1
Greece	11	8	4	4	2	6
Hungary	—	2	3	1	—	1
Ireland	1	—	—	2	—	—
Italy	4	14	5	3	2	6
The Netherlands	1	1	2	1	—	2
Norway	3	—	2	3	—	—
Poland	5	2	8	2	2	4
Portugal	8	—	3	—	—	3
Rumania	6	3	6	1	1	5
Spain	36	34	27	14	1	15
Sweden	3	—	3	—	—	—
Switzerland	2	2	3	—	—	2
USSR	5	—	—	—	—	1
Yugoslavia	7	—	6	4	2	5
North America	**58**	**22**	**21**	**14**	**5**	**0**
Canada	14	6	6	4	1	0
USA	44	16	15	10	4	0
Total nurseries	**1225**	**465**	**393**	**255**	**125**	**420**
Total countries	**88**	**61**	**79**	**66**	**50**	**82**

Appendix III

Countries of origin of maize in-service trainees, 1971-86

	1971-86	1986
Mexico, Central America, and Caribbean	**274**	**21**
Belize	6	—
Costa Rica	25	6
Cuba	4	—
Dominica	1	—
The Dominican Republic	21	1
El Salvador	30	2
Grenada	1	—
Guatemala	32	4
Guyana	1	—
Haiti	18	—
Honduras	36	3
Jamaica	1	—
Mexico	55	4
Nicaragua	26	1
Panama	17	—
South America	**122**	**9**
Argentina	13	1
Bolivia	13	—
Brazil	4	—
Colombia	15	—
Chile	2	—
Ecuador	26	2
Paraguay	4	1
Peru	37	4
Venezuela	8	—
Asia	**232**	**17**
Afghanistan	6	—
Bangladesh	14	1
Burma	1	—
China	2	1
India	10	—
Indonesia	13	1
Japan	7	—
Korea	2	—
Malaysia	3	—
Asia (continued)		
Nepal	27	1
Pakistan	49	3
The Philippines	32	2
Sri Lanka	1	1
Thailand	54	4
Vietnam	11	3
Middle East/North Africa	**67**	**9**
Algeria	1	—
Egypt	31	2
Iran	1	—
Morocco	1	1
Syria	4	2
Tunisia	3	—
Turkey	22	3
Yemen, North	4	1
Sub-Saharan Africa	**241**	**23**
Benin	2	—
Botswana	2	—
Burkina Faso	1	1
Burundi	2	1
Cameroon	5	1
Cape Verde	1	—
Congo	2	1
Ethiopia	10	2
Ghana	37	3
Guinea-Bissau	5	2
Ivory Coast	7	2
Kenya	17	3
Lesotho	1	—
Mali	1	—
Malawi	10	2
Mauritius	1	1
Mozambique	3	—
Nigeria	15	—
Rwanda	2	—
Senegal	3	—
Somalia	5	—
Swaziland	1	—
Tanzania	59	2
Transkei	1	—
Uganda	6	2
Zaire	32	—
Zambia	10	—
Other countries	**4**	**—**
Total trainees	**940**	**79**
Total countries	**78**	**39**

Appendix IV

Countries of origin of wheat in-service trainees, 1966-86

	1966-86	1986
Latin America	**260**	**19**
Argentina	18	2
Bolivia	28	3
Brazil	21	—
Chile	13	—
Colombia	9	1
The Dominican Republic	4	1
Ecuador	28	1
Guatemala	15	1
Guyana	2	—
Honduras	1	—
Mexico	67	5
Panama	1	—
Paraguay	11	2
Peru	40	2
Uruguay	1	—
Venezuela	1	1
North Africa/Middle East	**233**	**8**
Algeria	54	—
Cyprus	2	—
Egypt	18	2
Iran	10	—
Iraq	5	—
Jordan	7	—
Lebanon	4	—
Libya	4	—
Morocco	25	2
Saudi Arabia	2	—
Sudan	5	1
Syria	9	—
Tunisia	28	—
Turkey	57	3
Yemen	3	—
Sub-Saharan Africa	**124**	**21**
Burkina Faso	1	1
Burundi	1	—
Cameroon	6	1
Chad	1	—
Ethiopia	26	6
Ghana	1	1
Ivory Coast	1	1
Kenya	16	2
Lesotho	2	—
Madagascar	4	1
Malawi	4	1
Mali	3	—
Mozambique	1	—
Nigeria	22	4
Rwanda	2	—
Senegal	2	—
Somalia	1	—
Tanzania	15	1
Transkei	1	—
Uganda	3	2
Zaire	2	—
Zambia	7	—
Zimbabwe	2	—
Asia	**252**	**21**
Afghanistan	13	—
Bangladesh	53	2
Bhutan	1	1
Burma	2	—
China	3	—
India	19	—
Indonesia	4	2
Korea	19	—
Nepal	26	2
Pakistan	76	6
The Philippines	18	4
Sri Lanka	2	—
Thailand	15	4
Vietnam	1	—
Other Countries	**30**	**0**
France	1	—
Hungary	2	—
Norway	1	—
Poland	5	—
Portugal	5	—
Rumania	2	—
Spain	6	—
USA	4	—
USSR	4	—
Total trainees	**899**	**69**
Total countries	**77**	**32**

Appendix V

Publications released by CIMMYT in 1986

	Language	Pages	Pressrun
Administration			
1985 Annual Report	English	80	4,000
	Spanish	80	3,000
CIMMYT Budget Request 1987	English	36	1,000
CIMMYT Research Highlights 1985	English	132	4,000
CIMMYT's Information Service for Wheat,	English		4,500
Barley, and Triticale (brochure)	Spanish		2,500
Mainstreams of CIMMYT Research:	English	48	4,500
A Retrospective	Spanish	48	1,500
Norman E. Borlaug Building (brochure)	English	10	1,500
	Spanish	10	1,000
Strengthening National Research Programs Through	English	24	4,000
Training: A Twenty-Year Progress Report	Spanish	24	2,000
This is CIMMYT	English	48	1,500
	Spanish	48	1,000
	French	48	1,000
Maize			
A Common Ground for Maize Research:	English	22	5,000
Regional Cooperation in the Middle	Spanish	24	3,000
East and North Africa (CIMMYT Today No. 17)			
CIMMYT International Maize Testing Program	English	250	750
1984 Final Report			
Development, Maintenance, and Seed	French	20	1,000
Multiplication of Open-Pollinated			
Maize Varieties			
Improving on Excellence: Achievements in	English	28	2,000
Breeding with the Maize Race Tuxpeño	Spanish	32	1,000
Maize Diseases: A Guide for Field	Turkish	124	1,000
Identification	French	124	2,000
Seed Conservation and Distribution:	English	18	3,000
The Dual Role of the CIMMYT Maize	Spanish	18	1,500
Germplasm Bank			
To Feed Ourselves: A Proceedings of the	English	320	5,000
First Eastern, Central, and Southern Africa Regional			
Maize Workshop			
Wheat			
Cereal Diseases Methodology Manual	English	56	5,000
	Spanish	54	2,000
CIMMYT Report on Wheat Improvement 1984	English	198	3,000
Durum Wheat: Names, Parentage, Pedigrees,	English	108	1,500
and Origin	Spanish	108	1,000
Instructions for the Management and	Spanish	24	1,500
Reporting of Results for the CIMMYT			
Wheat Program International Nurseries			
Nursery reports:			
Results of the 6th International Barley	English	39	750
Yield Trial (IBYT) 1983-84			
Results of the 11th International	English	39	750
Barley Observation Nursery (IBON) 1983-84			
Results of the 15th International	English	58	750
Durum Yield Nursery (IDYN) 1983-84			
Results of the 15th International	English	68	750
Durum Screening Nursery (IDSN) 1983-84			
Results of the 13th Elite Durum	English	48	750
Yield Trial (EDYT) 1983-84			
Results of the 15th International	English	86	750
Triticale Yield Nursery (ITYN) 1983-84			

Appendix V (Continued)

Publications released by CIMMYT in 1986

	Language	Pages	Pressrun
Results of the 15th International Triticale Screening Nursery (ITSN) 1983-84	English	42	750
Results of the 17th International Bread Wheat Screening Nursery (IBWSN) 1983-84	English	73	750
Results of the 5th Elite Selection Wheat Yield Trial (ESWYT) 1983-84	English	69	750
Results of the 14th International Septoria Observation Nursery (ISEPTON) 1983-84	English	42	750
Results of the 20th International Spring Wheat Yield Nursery (ISWYN) 1983-84	English	94	750
Results of the Aluminum Resistance Screening Nursery (ARSN) 1983-84	English	22	20
Results of the Drought Tolerance Screening Nursery (DTSN) 1983-84	English	24	20
Results of the Early Maturity Screening Nursery (EMSN) 1983-84	English	18	20
Results of the Helminthosporium Resistance Screening Nursery (HRSN) 1983-84	English	20	20
Proceedings of the Fifth Biennial Smut Workers' Workshop	English	46	1,000
Spring Triticale: Names, Parentage, Pedigrees, and Origin	English	52	1,500
	Spanish	48	1,000
Veery 'S': Bread Wheats for Many Environments	English	28	2,000
	Spanish	28	1,000
Wheat Diseases and Pests: A Guide for Field Identification	English	148	10,000
	Spanish	148	5,000
Wheat Varieties of the Southern Cone Region of South America: Names, Parentage, Pedigrees, and Origins	English	72	1,000
	Spanish	78	1,500
Economics			
Comparative Advantage and Policy Incentives for Wheat Production in Ecuador	Spanish	126	750
Comparative Advantage and Policy Incentives for Wheat Production in Rainfed and Irrigated Areas of Mexico	English	118	1,000
Copublication of Bibliographic Journals			
Maize Abstracts (CAB)			
Vol.1, No.6	English	80	750
Vol.2, No.1	English	80	750
Vol.2, No.2	English	112	750
Vol.2, No.3	English	96	750
Vol.2, No.4	English	96	750
Vol.2, No.5	English	80	750
Wheat, Barley, and Triticale Abstracts (CAB)			
Vol.2, No.6	English	144	600
Vol.3, No.1	English	119	600
Vol.3, No.2	English	160	600
Vol.3, No.3	English	176	600
Vol.3, No.4	English	144	600
Vol.3, No.5	English	160	600
Wheat, Barley, and Triticale Abstracts, Vol.2, Annual Indexes	English	128	600
Wheat, Barley, and Triticale Bibliography, Vol.1, No.6, November-December 1985	English	116	750

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Price Waterhouse

México, D.F., February 22, 1987

To the Board of Trustees of
Centro Internacional de Mejoramiento
de Maíz y Trigo, A.C.

In our opinion, the accompanying statements of condition and the related statements of activity and of changes in financial position on a cash basis, expressed in United States dollars, present fairly the financial position of Centro Internacional de Mejoramiento de Maíz y Trigo, A.C. (CIMMYT) at December 31, 1986 and 1985, and the results of its operations and the changes in its financial position for the years then ended, in conformity with accounting principles generally accepted in the United States of America for not-for-profit organizations consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our examinations were made primarily for the purpose of forming our opinion on the financial statements taken as a whole. We also examined the additional information presented on Exhibits 1 to 4, expressed in United States dollars, by similar auditing procedures. In our opinion, this additional information is stated fairly in all material respects in relation to the financial statements taken as a whole. Although not necessary for a fair presentation of financial position, results of operations and changes in financial position, this information is presented as additional data.

Price Waterhouse

C.P. Oscar Córdova

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Comparative Statement of Financial Condition

Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Assets, Liabilities, and Fund Balances		Currency: US Dollars (000s)	
		Year ended December 31	
	Note[a]	1986	1985[b]
Assets			
Cash and short-term deposits	2	2,388	5,687
Accounts receivable			
Donors	6	1,570	1,130
Others	6	721	744
Inventories	2	95	88
Other assets			1
Property, plant, and equipment	2	19,300	16,658
Total assets		**24,074**	**24,308**
Liabilities			
Accounts payable and other liabilities		1,204	2,007
Accrued benefits	2	377	245
Payments in advance from donors	6	2,194	4,509
Total liabilities		**3,775**	**6,761**
Fund balances			
Property, plant, and equipment	2,4	19,300	16,658
Capital development	4	400	
Operating	4	2,415	2,415
Auxiliary services	4	138	159
Cumulative translation effect	3	(1,954)	(1,685)
Subtotal		999	889
Total fund balances		**20,299**	**17,547**
Total liabilities and fund balances		**24,074**	**24,308**

[a] The attached notes numbered 1 to 6 form an integral part of these financial statements.
[b] Reclassified for comparative purposes.

Comparative Statement of Activity

Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Revenue and Expenses — Currency: US Dollars (000s)

	Note[a]	Year ended December 31 1986	1985[b]
Revenue	5		
Grants		27,643	25,621
Administrative fees		1,369	1,139
Sale of crops		47	38
Interest on short-term investments		196	309
Auxiliary services		734	665
Other income		1	1
Total revenue		**29,990**	**27,773**
Operating Expenses	5		
Research programs		18,408	17,063
Conferences and training		3,921	3,659
Information services		697	905
General administration		1,834	1,857
Plant operations		1,306	1,463
Capital acquisitions		1,241	986
Auxiliary services		755	571
Indirect costs		1,369	1,139
Accrual benefits		80	36
Total operating expenses		**29,611**	**27,679**
Excess of revenue over operating expenses		379	94
Allocated as follows:			
Capital development fund	4	400	
Auxiliary services	4	(21)	94
Translation effect for the year	3	(269)	(312)
Net excess (defect) of revenue over expenses		110	(218)
Fund, opening balances		889	1,107
Closing fund balances as per statement of condition		999	889

[a] The attached notes numbered 1 to 6 form an integral part of these financial statements.
[b] Reclassified for comparative purposes.

Comparative Statement of Changes in Financial Condition on a Cash Basis

Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Currency: US Dollars (000s)

Operating activities	Note[a]	Year ended December 31 1986	1985[b]
Cash receipts:			
Grants from donors	5	27,643	25,621
Other	5	2,347	2,152
Subtotal		29,990	27,773
Translation effect for the year	3	(269)	(312)
Capital development fund	4	400	
Subtotal		30,121	27,461
Cash disbursements:			
Salaries and allowances		12,460	12,291
Travel		2,116	2,241
Training, conferences, and publications		3,601	3,205
Field and laboratory		3,399	4,030
Office and vehicle		3,975	2,379
Others		1,818	1,139
Subtotal		27,369	25,285
Cash provided by operating activities		2,752	2,176
Other activities:			
Additions to property, plant, and equipment	2	(2,642)	(2,394)
Accounts receivable from others	6	23	(315)
Accrued benefits	2	132	133
Inventories	2	(7)	125
Payments in advance from donors	2,6	(2,315)	2,960
Accounts receivable from donors	2,6	(440)	307
Accounts payable and other liabilities		(802)	(972)
Other assets			9
Cash used in other activities		(6,051)	(147)
(Decrease) increase in cash and short-term deposits		(3,299)	2,029
Cash and short-term deposits at beginning of year		5,687	3,658
Cash and short-term deposits at end of year		2,388	5,687

[a]The attached notes numbered 1 to 6 form an integral part of these financial statements.
[b]Reclassified for compartive purposes.

Notes to the Financial Statements

Centro Internacional de Mejoramiento de Maíz y Trigo

December 31, 1986, and 1985
US Dollars

Note 1: Statement of Purpose

The Centro Internacional de Mejoramiento de Maíz y Trigo, A.C. (CIMMYT), is a private, autonomous, not-for-profit, scientific and educational institution chartered under Mexican law to engage in the improvement of maize and wheat production everywhere in the world, with emphasis on developing countries.

Note 2: Summary of Significant Accounting Policies

CIMMYT follows accounting policies recommended by the Secretariat of the Consultative Group on International Agricultural Research (CGIAR), an international association sponsored by the World Bank, the Food and Agriculture Organization of the United Nations, and the United Nations Development Programme. In 1986 these policies were revised, and a standard presentation for all research centers supported by the CGIAR was adopted. These policies are in accordance with accounting practices generally accepted in the United States of America for not-for-profit organizations and are summarized below:

a. CIMMYT uses the accrual method of accounting for transactions, and its books of account are kept in US dollars. Transactions in other currencies (mainly Mexican pesos) are recorded at the rates of exchange prevailing on the dates they are entered into and settled. Assets and liabilities denominated in such currencies are translated into US dollars applying Statement No. 52 of the Financial Accounting Standards Board of The United States of America (FAS 52). In accordance with that statement, CIMMYT has adopted the US dollar as its "functional currency" in consideration that the Mexican economy has been hyper-inflationary, i.e., with a cumulative inflation rate for the three last years greater than 100 percent as measured by the National Consumer Price Index published by Banco de Mexico.

b. Purchase orders issued prior to December 31 are treated as operating expenses of the year in question and are shown on the statement of condition under vouchers payable. This is in accordance with guidelines issued by the CGIAR.

c. During periods of cash surplus, CIMMYT makes short-term investments in marketable securities. Those denominated in dollars are transacted in the US money market. Interest is credited to income when the security matures or is sold. The security is recorded at cost, which approximates market, and any gain or loss from its sale is recorded at that time. Investments in pesos are held in a short-term interest-bearing account in a Mexican bank or in government securities. Interest is credited to income as accrued.

d. Inventories are stated at cost (first-in, first-out method), which is not in excess of market.

e. Fixed assets are stated at acquisition cost: Up to 1971 all purchases of property and equipment were recorded as expenses. In 1972 the CGIAR requested that the International Agricultural Research Centers change to the "write off, then capitalize" method of recording purchases of property and equipment. Accordingly, all property and equipment purchased under capital grants as from January 1, 1972, were recorded as an asset and credited to capital grants. Prior to 1980 replacements of capital items were recorded as expenditures of the related programs and did not enter in any way to form part of CIMMYT's capital grants, shown on the statement of condition. In 1980 this policy was revised to conform with the accounting policies of the CGIAR. Under this set of guidelines, the incremental value of a capital replacement item, i.e., the amount by which the historical cost of the replacement item is greater (less) than the historical cost of the item being replaced, is credited (debited) to capital grants fully expended on fixed assets. In this way the statement of condition reflects the historical cost of the fixed assets actually in use.

CIMMYT's buildings at certain locations in Mexico are constructed on land owned by the Mexican government and will be donated to the government when CIMMYT ceases operations in Mexico.

f. Depreciation—In accordance with the "write off, then capitalize" method, no depreciation is provided since the assets have already been written off at the time of purchase.

g. Seniority premiums, to which employees are entitled upon termination of employment after 15 years of service, are recognized as expenses as such premiums accrue. The estimate of the accrued benefit determined on the basis of an actuarial study as of the year end amounted to $135,000 in 1986 ($143,000 in 1985), and CIMMYT has recorded a liability of $119,000 in 1986 ($126,000 in 1985). The charge to income for the year amounted to $83,000 in 1986 ($36,000 in 1985), including amortization of past service cost over 10 years.

Other compensation based on length of service, to which employees may be entitled in the event of dismissal or death, in accordance with the Mexican Federal Labor Law, is charged to income in the year in which it becomes payable.

Since 1985, CIMMYT has recorded an accrual for unutilized benefits, such as leave time, by staff. This amounted to $258,000 in 1986 ($119,000 in 1985).

h. Revenue Recognition—Core unrestricted grants are given annually and are charged to accounts receivable when the amount of the donation becomes known. The receivable is cancelled when the funds are received. Any uncollected portion of the pledge applicable to the current year remains charged to accounts receivable and forms part of the institution's income in that year. If the pledge is later judged to be uncollectible, it is written off against income of the year in which it is cancelled.

Pledges in currencies other than US Dollars are recorded at their equivalent at the date of deposit.

Core restricted and extra core pledges, which are often for more than one year, are treated somewhat differently. In these cases the amount recognized as a receivable is equal to the expenses incurred under the grant. The uncollected portion of the pledge is not recognized as a receivable and consequently does not contribute to income. Only when expenses are incurred under the grant is an account receivable created and income recorded. This treatment matches revenues and expenses in accordance with the level of activities carried out under the grant.

This accounting policy permits CIMMYT to distinguish between income and amounts pledged in core restricted and extra-core grants. This is necessary since these grants often cover more than one year's activities or contain carry-forward provisions in cases of underexpenditure. Recognizing the total pledge in a given year as income could result in an overstatement of income. Core unrestricted grants do not require this treatment since they are given annually and the amount pledged represents income that year.

Note 3: Mexican Peso Transactions
The foreign exchange system existing in Mexico as of July 1985 permits the parallel existence of controlled and free exchange rates handled through exchange brokerage houses with rates in the latter case set on the basis of supply and demand.

At December 31, 1986, CIMMYT had Mexican peso assets and liabilities amounting to Ps 365,895,000 (Ps 63,949,000 in 1985) and Ps 397,097,000 (Ps 139,341,000 in 1985), which were included in the statement of condition at their US dollar equivalents resulting from applying the year-end rate of Ps 911 per dollar.

In 1986 the value of the Mexican peso compared to the dollar fell from Ps 448 to Ps 911 to the dollar (Ps 209.22 to Ps 448.00 in 1985). This devaluation gave rise to a translation loss aggregating $269,000 ($312,000 in 1985). In accordance with FAS 52, where the firm is judged to be operating in a hyper-inflationary environment and the dollar is judged to be the functional currency, the translation effect in each year is charged to current income.

At February 27, 1987, date of issuance of the Financial Statements, the brokerage houses' exchange rates with the US dollar were Ps. 1,044 (buy) and Ps. 1,054 (sell).

Note 4: Fund Balances
The CGIAR permits CIMMYT (and all other international agricultural research centers funded through it) to maintain certain fund balances. The largest of these is the total investment in property, plant, and equipment. By the end of 1986, this had reached $19,300,000. A capital development fund may also be maintained to help finance future purchases or maintenance of capital items. In 1986, CIMMYT placed $400,000 in this fund.

An operating fund may also be kept for the purpose of smoothing out cash flows and year-to-year revenue streams. At the end of 1986, CIMMYT had $2,415,000 in operating funds. The surplus from CIMMYT's auxiliary services, such as food and housing, of $138,000 is also shown under fund balances. Lastly, the accumulated effect from the translation of Mexican pesos and other currencies is listed under fund balance and in 1986 amounted to $1,954,000.

Note 5: Revenue and Expenses
A. Revenue—CIMMYT's revenues are grouped into six categories:

i) Grants. These are funds received from donors and are used to support two types of programs at CIMMYT: core and extra core. Core programs must fall within the mandate of the center and be approved by the Board of Trustees. These must also be approved by the members of the CGIAR, who then provide funding. The CGIAR membership includes governments, government aid agencies, international and regional development banks, and private philanthropic foundations (see Exhibit 2). Core programs are divided into two groups: unrestricted and restricted. Unrestricted grants come with only one requirement: that the funds be used to support core activities. Restricted grants also support core activities, but they must be used for an activity mutually agreed upon by CIMMYT and the donor.

Extra-core programs must also fall within CIMMYT's mandate and also must be approved by the Board of Trustees. They fall outside of any direct funding through the CGIAR and may be considered related, but distinct, sets of activities from the core program. In general they are of four types: 1) direct assistance (i.e., posting of staff) to national programs, 2) training at CIMMYT for persons from a specific country, 3) collaborative research arrangements with other institutions, and 4) special exploratory research activities. Coordination of this type of funding is done between CIMMYT and the donor.

ii) Administrative fees. These fees are charged on restricted and extra-core grants. They permit CIMMYT to offset the cost of administering these grants, which by design only fund specific research activities. In 1986 and 1985, this fee was generally 15 percent, though for some on-campus activities it was 25 percent.

iii) Sale of crops. CIMMYT operates four experiment stations throughout Mexico. Grain and other produce not required for continuance of the research programs is sold from time to time depending on their availability and quality, and revenues received are registered as income of the period.

iv) Interest on short-term investments. Surplus cash is invested in short-term interest-bearing securities, and any interest earned is recorded as income. Similarly interest expense arising from short-term borrowings to cover cash deficit positions is charged to this account.

v) Auxiliary services. These comprise revenues from the following areas within CIMMYT: cafeteria, laundry, guest house, dormitories, and staff residences. As a whole, they are intended to be self-supporting.

vi) Other income. This is a grouping of miscellaneous revenues received from the sale of surplus items such as used tires and other small pieces of equipment no longer needed by CIMMYT.

B. Expenses—The breakdown of CIMMYT's expenses as shown in its statement of activity is largely self-explanatory. Included under Research Programs, the largest single expenditure, are the expenses of the Maize, Wheat, Economics, Experiment Stations, Laboratories, and Data Processing units. In 1986 and 1985, their expenses were as follows:

	1986 (000s)	1985
Maize	6,981	6,313
Wheat	6,853	6,678
Economics	1,680	1,334
Experiment Stations	1,410	1,530
Laboratories	401	386
Data Processing	840	693
Others	243	129
Total	18,408	17,063

Note 6: Accounts Receivable and Payments in Advance
Donors: In 1986 and 1985, these were comprised as follows:

Accounts Receivable From Donors	1986 (000s)	1985
Canadian International Development Agency	229	191
European Economic Community		129
Germany, The Federal Republic of	20	18
International Crops Research Institute for the Semi-Arid Tropics	9	26
International Institute of Tropical Agriculture	23	26
International Center for Agricultural Research in the Dry Areas	84	49
International Development Research Centre	56	
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank	90	54
OPEC Fund for International Development	69	30
Switzerland, Government of	326	
The Netherlands, Government of	73	39
United Nations Development Programme	207	152
United States Agency for International Development	331	362
Other donors	53	54
Subtotal: Accounts receivable from donors	1,570	1,130
Payment in Advance From Donors		
Australia, Government of	(60)	(99)
Canadian International Development Agency	(112)	(509)
Denmark, Government of	(67)	
Germany, The Federal Republic of	(32)	(35)
International Development Research Centre	(19)	(25)
Italy, Government of	(937)	(712)
The Japan Shipbuilding Industry Foundation and Government of Japan	(600)	(785)
Switzerland, Government of	(53)	(1,406)
The Ford Foundation	(112)	(24)
United States Agency for International Development	(11)	(13)
United Nations Development Programme	(65)	(70)
World Bank	(15)	(750)
Other donors	(111)	(81)
Subtotal: Payments in advance from donors	(2,194)	(4,509)
Net status of donors' payments	(624)	(3,379)

Others: In 1986 and 1985, these were as follows:

Receivables (payments)

	1986 (000s)	1985
Loans to senior staff	208	253
Personal charges to employees	(22)	(26)
Official expenses advances	450	462
Employee credit union	(49)	(28)
Miscellaneous debtors	134	83
Total	721	744

A program of loans to senior staff, mainly to provide partial financing for house purchases, was initiated in 1982. These carry an interest rate of prime plus 1.75 percent.

Detailed Statement of Activity For the Period January 1 to December 31, 1986
Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Exhibit 1 — **Currency: US Dollars (000s)**

	Core unrestricted	Core restricted	Extra core and cooperative	Auxiliary services	Total
Revenue (Note 5)					
Grants	16,019	5,188	6,436		27,643
Administrative fees	1,369				1,369
Sale of crops	47				47
Interest on short-term investments	196				196
Auxiliary services				734	734
Other income	1				1
Total revenue	**17,632**	**5,188**	**6,436**	**734**	**29,990**
Expenses (Note 5)					
Research programs	11,358	3,171	3,879		18,408
Conferences and training	1,645	1,335	941		3,921
Information services	697				697
General administration	1,834				1,834
Plant operations	1,306				1,306
Capital acquisitions	312		929		1,241
Auxiliary services				755	755
Indirect costs		682	687		1,369
Accrual benefits	80				80
Total operating expenses	**17,232**	**5,188**	**6,436**	**755**	**29,611**
Excess defect of revenue over operating expenses allocated as follows:	400			(21)	379
Capital development fund (Note 4)	400				400
Auxiliary services (Note 4)				(21)	(21)
Translation effect for the year (Note 3)	(269)				(269)
Net excess defect of revenue over expenses	131			(21)	110

Sources of Income from Grants For the Period January 1 to December 31, 1986
Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Exhibit 2 Currency: US Dollars (000s)

	Unrestricted	Restricted	Extra core and cooperative	Total
Australia, Government of	578		74	652
Austria, Government of	250			250
Canadian International Development Agency	1,216		2,148	3,364
China, People's Republic of	80			80
Denmark, Government of	363		16	379
European Economic Community		22		22
France, Government of		341		341
Germany, The Federal Republic of	447	30	67	544
Inter-American Development Bank	3,901			3,901
International Center for Agricultural Research for the Dry Areas			35	35
International Crops Research Institute for The Semi-Arid Tropics			236	236
International Development Research Centre			67	67
International Institute of Tropical Agriculture			62	62
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank			91	91
Ireland, Government of	102			102
Italy, Government of			425	425
Japan, Government of		1,480		1,480
Mexico, Government of			48	48
OPEC Fund for International Development		145		145
Spain, Government of	115			115
Switzerland, Government of		1,155	598	1,753
Norwegian Agency for International Development	145	62		207
The Ford Foundation	100	2		102
The Japan Shipbuilding Industry Foundation and Government of Japan			827	827
The Netherlands, Government of		333		333
The Philippines, Government of	54			54
The Rockefeller Foundation			10	10
The United Kingdom, Government of	878		150	1,028
United Nations Development Programme		1,618		1,618
United States Agency for International Development	6,100		1,412	7,512
World Bank	1,690			1,690
Miscellaneous training and research grants			170	170
Total income from grants	**16,019**	**5,188**	**6,436**	**27,643**

Core-Restricted Pledges and Expenses For the Period January 1 to December 31, 1986
Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Exhibit 3 **Currency: US Dollars (000s)**

	Grant period[a] (month/day/year)	Grant pledged[a]	--------Expenses------- Prior years	This year	Total
Government of France					
Collaborative Research, Maize	01/01/86-12/31/86			174	174
Bread Wheat	01/01/86-12/31/86			54	54
Triticale	01/01/86-12/31/86			54	54
Economics	01/01/86-12/31/86			59	59
Total		**341[b]**	**N/A**	**341**	**341**
Government of Japan					
Wheat Disease Surveillance	01/01/86-12/31/86			387	387
Wheat and Maize Plant Protection	01/01/86-12/31/86			719	719
Wheat, Southern Cone	01/01/86-12/31/86			374	374
Total		**1,480[c]**	**N/A**	**1,480**	**1,480**
OPEC Fund for International Development					
Maize West Africa, Phase III	07/01/85-06/30/86	125	61	76	137
Maize West Africa, Phase IV	07/01/86-06/30/87	125	N/A	69	69
Total		**250**	**61**	**145**	**206**
Government of Switzerland					
Central America and Caribbean, Maize	01/01/85-12/31/86		366	823	1,189
Central America and Caribbean, Economics	01/01/85-12/31/86		243	332	575
Total		**1,764**	**609**	**1,155**	**1,764**
Government of The Netherlands					
Economics	01/01/86-12/31/86	118	N/A	118	118
Computer Programmer	01/06/83-12/31/86	421	252	215	467
Total		**539**	**252**	**333**	**585**

Continued next page

Exhibit 3 (Continued)

Currency: US Dollars (000s)

	Grant period[a] (month/day/year)	Grant pledged[a]	Expenses Prior years	Expenses This year	Expenses Total
United Nations Development Programme					
International Maize Testing Program and Selected Training Activities	01/01/85-12/31/89	5,022	868	959	1,827
Tropical Wheat	07/01/82-06/30/87	2,415	1,419	659	2,078
Total		**7,437**	**2,287**	**1,618**	**3,905**
European Economic Community					
Andean Regional Wheat and Maize	03/12/83-12/31/86	1,618[d]	1,593	22	1,615
Norwegian Agency for International Development					
Wheat and Maize Training	01/01/86-12/31/86	62[e]	N/A	62	62
The Ford Foundation					
East Africa	09/24/81-12/31/86	256	243	2	245
Government of Federal Republic of Germany					
Wheat Improvement Program	07/01/83-06/30/86	291	289	30	319
International Development Research Centre					
Data Processing	11/02/84-11/02/87	160[f]	105		105
Total Core Restricted			**5,439**	**5,188**	**10,627**

[a] For information purposes only.
[b] Equivalent to FF 2,300,000
[c] Equivalent to YEN 229,680
[d] Equivalent to ECU 2,000,000
[e] Equivalent to NOK 450,000
[f] Equivalent to CA 197,000

N/A = Not applicable.

Extra-Core Pledges and Expenses For the Period January 1 to December 31, 1986

Centro Internacional de Mejoramiento de Maíz y Trigo, A.C.

Exhibit 4 Currency: US Dollars (000s)

	Grant period[a] (month/day/year)	Grant pledged[a]	Expenses Prior years	Expenses This year	Expenses Total
The Ford Foundation					
Economics and Training, Algeria	09/01/79-12/31/86	680	670	10	680
United States Agency for International Development					
Pakistan Agricultural Research Council, Wheat, Maize, and Economics	10/01/84-09/30/87	3,543[c]	1,034	713	1,747
Miscellaneous Training	b	N/A		7	7
Africa On-Farm Research, Phase II	01/01/86-05/20/90	5,000		691	691
Agronomic Wheat Production	08/01/85-11/30/85	25	12	2	14
Total		**8,568**	**1,046**	**1,413**	**2,459**
United Nations Development Programme					
Turkey, Wheat	12/31/83-03/01/86	263	241	150	391
Canadian International Development Agency					
Triticale Research and Training	04/01/78-12/31/86	286[d]	273	5	278
Haiti Economics Program, Phase II	01/01/85-12/31/88	564[e]	85	178	263
East Africa Cereals Program	10/01/84-03/31/88	2,118[f]	409	586	995
Ghana Maize, Phase II	10/01/83-09/30/88	3,803[g]	1,519	726	2,245
Bangladesh, Wheat	04/01/82-03/31/87	3,744[h]	1,595	586	2,181
East Africa Consultancy	12/13/85-03/31/86	53[i]		67	67
Total		**10,568**	**3,881**	**2,148**	**6,029**
Government of Switzerland					
Central America and Caribbean Seed Production	07/01/83-12/31/86	1,047	366	577	943
Economics Training	08/19/86-08/18/89	209		21	21
Total		**1,256**	**366**	**598**	**964**
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank					
Wheat	08/01/83-12/31/87	482	303	91	394
Government of Federal Republic of Germany					
Maize Improvement Program	01/01/83-05/15/86	129	91	4	95
Wheat International Agricultural Research	07/01/86-06/30/89	591		60	60
Enhancement of Disease Resistance in Quality Protein Maize	07/01/86-06/30/88	190		3	3
Total		**910**	**91**	**67**	**158**

Continued next page

Exhibit 4 (Continued) **Currency: US Dollars (000s)**

	Grant period[a] (month/day/year)	Grant pledged[a]	Expenses: Prior years	This year	Total
Government of Italy					
Barley Yellow Dwarf Virus	01/11/84-10/31/89	1,477	193	425	618
Government of Mexico					
Research	01/01/86-12/31/86	48[j]	N/A	48	48
The Japan Shipbuilding Industry Foundation and Government of Japan					
Training Building	11/01/84-12/31/86	1,730[k]	903	827	1,730
International Development Research Centre					
Bibliographic Service on Wheat and Small Grains	01/01/84-12/31/86	53[l]	8	8	16
Information Services on Wheat and Small Grains	06/29/84-06/30/87	295[m]	97	59	156
Database Management	11/02/84-11/02/86	160[n]	18		18
Total		**508**	**123**	**67**	**190**
Biotechnology Consortium					
Government of Australia	01/09/84-01/09/86	114[o]	15	74	89
Danish International Development Agency					
DPS Associate Scientist	09/01/86-08/30/89	137		16	16
International Institute of Tropical Agriculture					
SAFGRAD	01/01/86-12/31/86	N/A	N/A	62	62
Miscellaneous Training Grants	b	N/A	N/A	169	169
Cooperative Projects					
ICARDA, Barley Project	01/01/86-12/31/86	N/A		35	35
ICRISAT, Sorghum Project	01/01/81-12/31/86	1,395	917	236	1,153
Total		**1,395**	**917**	**271**	**1,188**
Total Extra Core			**8,749**	**6,436**	**15,185**

[a] For information purposes only.
[b] Grant period not applicable; donor pays tuition for each trainee sponsored.
[c] Includes RPs 24,533,105, equivalent to U.S. $1,423,860.
[d] Equivalent to CA 338,944
[e] Equivalent to CA 778,395
[f] Equivalent to CA 2,753,000
[g] Equivalent to CA 4,754,300
[h] Equivalent to CA 4,680,000
[i] Equivalent to CA 72,000
[j] Equivalent to MPs 44,000,000
[k] Includes US$144,600 of interest earned.
[l] Equivalent to CA 65,888
[m] Equivalent to CA 387,075
[n] Equivalent to CA 196,750
[o] Equivalent to AD 140,000

N/A = Not applicable.

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The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, the Center is engaged in a worldwide research program for maize, wheat, and triticale, with emphasis on food production in developing countries. It is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 40 donor countries, international and regional organizations, and private foundations.

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