CIMMYT 1987 Annual Report

International Maize and Wheat Improvement Center

A Dialogue with the Future

Trustees in 1987

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1 Resigned June 1987.
2 Ex-officio position.

CIMMYT 1987 Annual Report

International Maize and Wheat Improvement Center

A Dialogue with the Future

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CIMMYT and the CGIAR

The International Maize and Wheat Improvement Center (CIMMYT) is an international, nonprofit, scientific research and training organization. From its headquarters in Mexico and offices at 20 other locations across the Third World (see map, page 15), the Center operates a global program of maize, wheat, and triticale improvement; investigates economics issues related to these crops; and supports the 100 or so national agricultural research systems responsible for them in developing countries. CIMMYT is one of 13 centers supported by the Consultative Group on International Agricultural Research (CGIAR or CG), which is cosponsored 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's membership includes various donor countries, international and regional organizations, and private foundations.

Training is a central part of CIMMYT's strategy for strengthening national agricultural research programs.

The Origins of CIMMYT

Though now international in character, the Center grew directly out of national experience in Mexico and from the country's long and fruitful relationship with the Rockefeller Foundation. After conducting a survey of Mexican crop production in 1941 (arranged by Mexico's Minister of Agriculture and the US Vice-President), the Foundation assembled a small team of specialists in research, education, and extension, who joined Mexico's newly established Office of Special Studies within the agricultural ministry.

That group enjoyed considerable success, helping Mexico to become nearly self-sufficient in maize and wheat by the mid-1950s. One of its most notable achievements was the development of high-yielding semidwarf wheat varieties, which quickly spread from their Mexican proving ground to other wheat-producing countries, including India and Pakistan. After the closing of the Office of Special Studies in 1961, international dissemination of the Mexican wheats was continued under a new cooperative arrangement between the Rockefeller Foundation and Mexican Ministry of Agriculture, which was formed at the suggestion of Adolfo López Mateos (then president of Mexico) and ultimately led to the establishment of CIMMYT.

The Spread of High-Yielding Varieties

In 1963 new wheat varieties were already starting to show promise in India and Pakistan and by 1967 were being planted extensively in these countries. The result was a sharp increase in their wheat production and the beginning of more widespread adoption of high-yielding wheat varieties in the Third World, a phenomenon that benefitted millions of farmers and consumers directly and brightened the prospects of many more by demonstrating the worth of investment in both national and international agricultural research. That it consisted not just of the scientific achievements of a few exceptional individuals but of a push for advancement by many thousands was underscored by Norman E. Borlaug, who engineered the development of the new semidwarf wheats and for this work received a Nobel Peace Prize in 1970: "I am but one member of a vast team made up of many organizations, officials, thousands of scientists and millions of farmers—mostly small and humble—who for many years have been fighting a quiet, oftentimes losing war on the food production front."

The gathering momentum of the movement whose spirit he captured in that statement encouraged the Rockefeller and Ford Foundations to develop a succession of international agricultural research centers during the 1960s: first the International Rice Research Institute (IRRI) established in the Philippines during 1961, then CIMMYT in 1966, and shortly afterwards the International Institute of Tropical Agriculture (IITA) in Nigeria and International Center of Tropical Agriculture (CIAT) in Colombia (see map).

Formation and Role of the CGIAR

The complexity and extent of the research in which the centers were engaged soon made it apparent that new arrangements would have to be made to establish additional centers, guide their management, and ensure their long-term financial support. That recognition prompted a series of international brainstorming sessions and deft negotiations that led to the formation in 1971 of the CGIAR.

This body is unique in its simple, informal organization and in its influence, of which it is useful to distinguish two types, one having to do with finances and the other with the direction of agricultural research.

Through an innovative approach based on commitment and consensus, the CG has managed to enlarge the financial base of the centers from an initial annual budget of US$9 million to nearly US$200 million in 1987. CIMMYT's donors now include (in addition to its original benefactors, the Ford and Rockefeller Foundations) the international aid agencies of 22 countries and the European Economic Commission, Inter-American Development Bank, International Development Research Centre, OPEC Fund for International Development, UNDP, and World Bank (see Financial Statement, pages 62-77, for details on donor contributions).

In guiding the work of the centers, the CGIAR tries to ensure that they are not merely skirmishing with any foe of crop production that raises its head at a given time and place but are moving decisively to confront problems of international scope and continuing importance. Those are identified and articulated by the CG's Technical Advisory Committee (TAC), which consists of prominent scientists from around the world and whose secretariat at FAO headquarters is provided by the CG's three cosponsors. The challenge of each center is to reconcile the views and recommendations of TAC with its own capabilities and experience and then devise efficient, cost-effective approaches for tackling the problems that it considers most important and against which it can expect to make significant progress in a reasonable amount of time.

Through that process the work of the centers has evolved with changes in the circumstances and capabilities of developing countries and their agricultural research systems. Up to the early 1970s, for example, the overriding concern of the CG system was to increase production of the Third World's staple food crops, and considerable progress was made in that task, particularly in Asia and Latin America. Although it is no less deeply involved in the fight against hunger now than it was then, the CG system has come to view this struggle somewhat differently, giving less emphasis to increased production per se and more to the generation of additional income by the poor through improved agricultural technology.

Other CG concerns that will be reflected increasingly in the research programs of the centers are to sustain advances in crop productivity (which are threatened by the emergence of new strains of pests), to develop agricultural technologies that avoid or limit damage to the natural resources needed for future crop production, and to increase the productivity of rainfed agriculture in marginal areas characterized by high incidence of biotic and abiotic stresses. Making headway in those quite formidable undertakings will require, perhaps even more than did the production campaigns of which Borlaug spoke in his Nobel lecture, a massive collective effort by farmers, agriculturalists, and donors.

The 13 international agricultural research centers supported by the CGIAR.

Report From CIMMYT Management

Our dialogue with the future is a deliberate act of the imagination informed by hard data and educated opinions.

In 1987, CIMMYT's diverse programs in research, training, and support to national agricultural research programs continued apace. At the same time, most of the Center's staff contributed to a comprehensive assessment of our future directions by participating in the Center's strategic planning process. We have tried to convey the most distinctive features and chief advantages of that particular approach to planning in the expression "a dialogue with the future," which appears on the front cover of this *Annual Report*. What we mean to suggest by that phrase is a deliberate act of the imagination informed by hard data and educated opinions. Our dialogue with the future involves consultation with clients and colleagues, introspection, and predictions about the environmental circumstances in which the Center will likely find itself in the year 2000 and beyond. It also involves a careful examination of the criteria we will use to shape our future priorities.

Out of that dialogue, we will produce a plan that specifies the strategies by which we will proceed from our present reality toward our expected future. Those strategies will be predicated first upon the needs of our national program clients. In addition, they will reflect anticipated advances in science, insights into the likely role of the private sector and other alternative suppliers of CIMMYT's products and services, and projected changes in the global economic and physical environments. Our strategic plan will thus provide us with a means of better rationalizing decisions about resource allocations among competing activities. If an activity fits the plan, it will become or remain a part of our program; if not, we will leave it for others to pursue. Given the uncertainties associated with planning in research, however, we recognize the need for flexibility, for ensuring that the CIMMYT plan is able to accommodate unforeseen events. Hence, the planning process will be, not a one-time event, but a continuing discourse on our actions and their relation to the unfolding future.

The origins and underlying concepts of strategic planning are very ably explained by our guest contributor, Dr. Selcuk Ozgediz, in the next section, which is entitled Point of View. Dr. Ozgediz has devoted his professional life to working on issues related to planning and, in his capacity as management adviser to the CGIAR Secretariat, outlined a strategic planning process for us during a session held at CIMMYT headquarters in 1986.

His essay is the centerpiece of the first in a new series of *CIMMYT Annual Reports*. Each report will be oriented toward a particular theme or issue of abiding interest to donors, our colleagues in national agricultural research systems (NARSs), and other institutions concerned with agricultural development. In the Point of View section of each report, we will offer readers an expert assessment of the relevant theme or issue. While adding that and other elements to the *Annual Report*, we are discontinuing the *Research Highlights* series. We expect to retain the most useful features of the latter in other forms by channeling more of our information resources into technical bulletins and by packing more details about our science and related activities into the *Annual Report*, primarily in brief articles on specific topics. We believe that these changes will increase the report's interest and utility.

A Progress Report on Strategic Planning

As of this writing, we are well on our way to producing a strategic plan. The task is not complete, and much reviewing and redrafting still lies ahead. The resulting document will encompass a large body of information generated in 1987 by numerous CIMMYT staff and others on a wide range of issues.

That work got underway early in 1987 with the establishment of a standing committee to guide the planning process and of several task forces composed of senior scientific staff and other specialists. The latter were charged with examining the many issues and opportunities associated with 1) germplasm development, 2) crop management research, 3) basic and strategic research, 4) training, 5) information, and 6) NARSs. A subset of the standing committee was designated to seek ideas from still other CIMMYT staff and, finally, to draft the plan.

In September 1987 the reflections of the various task forces were shared with 22 representatives of key NARSs during a two-day symposium held at Center headquarters. The purpose was to enable us to obtain *their* views about the future needs of NARSs, to receive feedback on the work we had done up to that point, and to seek their counsel concerning issues we may have overlooked. The symposium was a first crucial step in shaping our impressions about the probable needs and circumstances of NARSs toward the year 2000. Following the symposium, a much larger sampling of the opinions of national program staff was obtained by way of a questionnaire covering much the same issues discussed in September.

By mid-January 1988, the standing committee had finished its first draft of the plan, and later in the month, it was discussed by all of our headquarters and outreach staff and afterwards revised. Then, in February 1988 we went back to the national programs, meeting with selected representatives in regional sessions held in Colombia, Kenya, and Thailand. After making adjustments called for by the outcome of those sessions, we shared the draft plan with CIMMYT's Board of Trustees in late March. Once the views of all groups concerned have been taken into account, a modified draft will be delivered in June to the CGIAR external program and management review teams. The teams will present us with their comments on the plan in August, and these will be factored into a final version of the plan.

Elements of Strategic Planning

Let me come back now to the questions of CIMMYT's future operating environment and of the criteria we will use in establishing priorities. First, what are the important environmental elements that we need to assess now to facilitate decision making tomorrow? Of obvious importance is the pace of progress achieved by national programs. To what extent will their progress during the coming decade require changes in CIMMYT's offerings, and how do we ensure that the Center's products and services stay abreast of national program development? In answering those questions, we will rely heavily on the guidance obtained during the various meetings we have held with NARS representatives. We are also looking at other developments (ranging from the activities of private seed companies to expected trends in the availability of computers) that will shape the future environment of national agricultural research in the developing world and CIMMYT's response to it.

Other important elements of the future that the Center and its clients will watch closely are changes in science, trends in the markets for maize and wheat, and projections concerning our physical environment. Changes in science will add to our research capacity in the coming decade and will determine to a large extent how rapidly we can improve the efficiency of our germplasm development programs. Trends in the markets for maize and wheat will influence the mix of products we will provide. If we believe, for example, that a high and increasing proportion of the wheat produced in developing countries will be consumed in the form of processed foods, then we will need to be relatively more concerned with the quality traits of the Center's wheat germplasm. Similarly, if current data suggest a trend toward greater use of maize as feed rather than food, then yellow maize will assume relatively greater importance in our breeding efforts. And monitoring changes in the physical environment will help us determine the relative priorities we should assign to various classes of research, such as tolerance to abiotic stresses or issues related to sustainability.

National programs, other suppliers of our products and services, advances in science, market trends, changes in the physical environment—those are among the phenomena and inhabitants that make up the geography of our institutional environment. We must also keep in view two others, the CGIAR and TAC, whose members have an important influence on the ultimate aims of research conducted by CIMMYT and its sister institutes. In general, the

In preparing the strategic plan, CIMMYT drew in various ways upon the experience of national scientists, whose relationships with the Center have been reinforced over the years through visits to its experiment stations in Mexico. Here CIMMYT entomologist Alejandro Ortega C. (right) points out insect larvae to Li Zhiliang, Vice-Director of the Chengde Institute of Agricultural Science, China, and Belaid Sali, director of Morocco's maize program.

Progress in national programs, advances in science, market trends, changes in the physical environment—those are among the phenomena that make up the geography of our institutional environment.

CGIAR has indicated that the research and related activites of the centers should be international in character, that we should strive for efficiency in the use of our scarce resources, and that our efforts should be of particular benefit to the poor. Given those System-wide parameters, we are developing a set of more specific criteria for assigning priorities in allocating CIMMYT's resources.

Clearly decisions about priorities and resource allocations rest on judgments about what is more and what is less important to attaining CIMMYT's goals. It is also evident that we are dealing with multidimensional goals. Identifying those goals and their related decision criteria has been an important part of our efforts in strategic planning.

Our point of departure relative to resource allocation is a measure of the value of extra output we can expect from various lines of work. Those values, based on markets, have been modified to reflect the CG System's emphasis on the poor. Beyond that, but still in relation to the poor, we have examined the possible inclusion of weights for nutrition, for food versus feed, for stability, and for the role of agriculture as an engine of growth. Concerns for efficiency led us to consider such factors as alternative sources of supply, upstream research, and minimum critical mass. Finally, because of specific CG concerns, we have considered special weights for marginal lands, for sustainability, and, again, for upstream research. In examining those criteria, we have been concerned with decision making at all levels of the Center so as to ensure consistency wherever priorities are being developed.

While thus exploring our institutional environment, predicting its future, and contemplating the appropriateness of alternative decision criteria, we are also reexamining the familiar internal landscape of CIMMYT to identify our current strengths and weaknesses and to determine whether our mix of resources will be adequate to meet the challenges and difficulties that loom on the horizon. The structure of the institution, its staffing pattern, physical facilities, and funding base have all been subject to close scrutiny; assessments of future requirements and options are receiving full attention in our plan.

Changes in the Directing Staff

Several important changes in CIMMYT's Directing Staff occurred during 1987 and early 1988. First, Dr. Derek Byerlee (Australian; agricultural economist; formerly a CIMMYT regional economist in South Asia, stationed in Islamabad, Pakistan) assumed new responsibilities as Director of the Economics Program as of June 1987. Special thanks are due to Dr. Rob Tripp of the Economics Program, who served as Acting Director for nearly two years while Dr. Byerlee completed a sabbatical leave.

Dr. Byrd Curtis, Director of the Wheat Program since October 1981, announced his decision in November to focus exclusively on coordinating the Center's activities within North Africa and the Middle East, effective March 1, 1988. After an extensive international search, Dr. Tony Fischer (Australian; plant physiologist; Senior Principal Research Scientist, Division of Plant Industry, Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra; member and former Chairman of the Program Committee, Board of Trustees, International Center for Agricultural Research in the Dry Areas (ICARDA); and staff member of CIMMYT's Wheat Program from 1970 to 1975) was selected as the new Wheat Program Director. Dr. Fischer will assume his duties in October 1988. After 17 years with CIMMYT, Dr. Arthur Klatt, Associate Director of the Wheat Program since July 1979, decided to accept an appointment as Assistant Dean for International Programs in Agriculture, Oklahoma State University, effective January 1, 1988. Dr. Klatt's successor is Dr. George Varughese (Indian; cytogeneticist and plant breeder; 20 years with CIMMYT in various capacities; Head of our Triticale Program since 1984). Dr. Varughese assumed his new duties in March 1988.

Finally, Dr. Clive James, Deputy Director General for Research since April 1981, announced his decision to relinquish the responsibilities of DDG-Research as of March 18, 1988, in order to pursue other career options. Dr. James will focus his energies initially as a consultant to CIMMYT, seeking ways to broaden the Center's funding base. The search for Dr. James successor is now underway.

The Activities of CIMMYT's Programs in 1987

We have gone out of our way in this Report From CIMMYT Management to stress the future and its contingencies, primarily because we wish to distinguish strategic planning from other approaches that assume a more static environment and the persistence of current

Highlights From 1987

- After several cycles of intensive selection for resistance to northern leaf blight, a major disease of maize in the subtropics, breeders were able to demonstrate improved resistance in their elite populations for that ecology (page 17).
- The results of international testing confirmed improved resistance to various borer species and fall armyworm in a special multiple-borer-resistance material. A conference was held to bring together ideas on the best available techniques for developing host plant resistance to maize insects (page 22).
- A panel of internationally recognized scientists met at CIMMYT headquarters to review the current status of rust resistance in wheat and to develop future resistance breeding strategies; results of those deliberations have now been published (page 31).
- The Wheat Program established a breeding partnership with China, in which CIMMYT and national program breeders are striving to develop improved resistance to fusarium head scab; alternate generations are being grown in Mexico and China, and the partnership is characterized by joint decision making (page 33).
- In a study of maize-based farming systems in northern Pakistan, procedures were developed for valuing green and dry fodder to assess the relative importance of grain and fodder in the farming system. That was a critical first step toward framing improved technologies (page 46).
- A workshop was held at Bogor, Indonesia, for senior research managers and analysts from six Asian countries (along with resource persons from various universities and development organizations) to explore applications of economics concepts to the allocation of research resources (page 48).

circumstances into the foreseeable future. Having done so, however, we would add that our staff approach the task of planning CIMMYT's next two decades with a strong sense of its 20-year history and of the even longer experience of its predecessor organizations. The legacy of that period is very much reflected in the CIMMYT of today and in this report on its activities in 1987.

Central to that work are the international maize and wheat testing networks that CIMMYT coordinates, which receive improved germplasm from our own breeding programs and from those of cooperating national programs. The Center's research also includes a sizeable economics component, which consists largely of the development and teaching of widely applicable procedures for on-farm research, policy analysis, and other types of investigations. All of that work is complemented by our training programs, regional operations, and bilateral projects.

As you will see in the Review of CIMMYT Programs, which follows the contribution to this report by Dr. Ozgediz, important steps were taken during the past year to improve both the efficiency and quality of our breeding, crop management, and economics research and to further enrich our relationships with clients in national programs. A sense of the substance and diversity of those endeavors is given in the accompanying list of highlights (see box).

Our own exertions were matched by strong support from the donors in 1987. We trust that this report, with its recounting of our research and accounting of how we deployed donor funds, amply demonstrates our fulfillment of an international public trust to scores of national agricultural research systems and the millions of farmers they serve throughout the developing world.

Donald L. Winkelmann
Director General

May 1988

Point of View
Concepts and Issues in Strategic Planning

Selcuk Ozgediz, Management Adviser, CGIAR Secretariat

Mission-oriented, nonprofit research organizations such as the international agricultural research centers supported by the CGIAR are finding themselves under increasing pressure to justify their existence. The pressure stems, in part, from increasing scarcity of and competing demands for donor funds for research and related activities. It is reinforced by the uncertainty of realizing high returns from investments in long-term research projects. Many organizations have turned to long-term strategic planning as a means of responding to those pressures.

The Origins of Strategic Planning

Strategic planning is a reaction to the inadequacies of planning systems used in the 1950s and 1960s. Financial planning approaches, such as the planning, programming, and budgeting system (PPBS) and zero-based budgeting, placed heavy emphasis on short-term efficiency at the expense of long-term positioning of the organization. Traditional long-range planning, on the other hand, relied on forecasting based on past trends, often leading to formulation of detailed multiyear blueprint plans that quickly became obsolete (Hanna 1985; Porter 1987).

The origins of strategic planning lie in the US private sector. Its conceptual foundations go back to the work of the Harvard Business School in the 1950s to develop the best "fit" between an organization and its environment. One of the first major applications of strategic planning was the pioneering work in General Electric Corporation in the 1960s on ways of deciding how corporate resources should be allocated to different strategic business units (Hamermesh 1986). Since then several approaches have emerged with titles such as strategic planning systems, stakeholder management, strategic issue management, portfolio analysis, and competitive analysis. The use of strategic planning in the public and private nonprofit sectors, however, has so far been limited (Bryson and Roering 1987).

The Concept of Strategy

Although there is some confusion in the management literature about the precise meaning of strategy (Von Neumann and Morgenstern 1944; Chandler 1962; Tilles 1963; and Mintzberg and Waters 1985), one can discern several common threads running throughout the various definitions. First, they have an action orientation in the sense of providing a guide to action; second, they emphasize specifying a course of action; and third, they view long-term goals as part of an organization's strategy. The latter point is especially prominent in Tilles' definition of strategy as "a set of goals and major policies." By goals Tilles means what an organization is aspiring to achieve as well as what it, in its totality, wishes to become in the long term. Major policies, on the other hand, refer to key decision rules that can guide the making of specific choices.

The definition I use is as follows: An organization's strategy describes the most desirable vision of its future, outlines the essential elements of a course it intends to follow to realize that vision, and provides a justification for the identified course. That definition contains the three features mentioned above, but I have included a fourth element—justification of the course to be followed—that is particularly important for nonprofit institutions.

Levels of Strategy

In the literature on corporate planning, a distinction is often made between enterprise, corporate, and business strategy. Enterprise strategy refers to what the company as an

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The views expressed here are those of the author and do not necessarily reflect the views of the World Bank, the CGIAR Secretariat, or CIMMYT.

institution stands for (Freeman 1984) and includes answers to such questions as: What is our basic character as an organization? What is our place in the world? And what values do we subscribe to? Corporate strategy answers the questions: What businesses should we be in, and how should we allocate our resources to them? Business strategy addresses questions of direction and competitive positioning (Hamermesh 1986), such as: Where should we be headed in this business, and what policies or courses of action should we adopt to succeed?. All three major levels of strategy are relevant to autonomous research organizations, even if they are not part of a larger corporation like IBM or General Electric.

Our definition of strategy encompasses the three levels of strategy. The vision of the organization's future relates mainly to enterprise- and corporate-level questions. The course to be followed by the organization covers corporate-level resource allocation questions and the specific direction to be pursued in each business. Our stress on the need for spelling out the rationale for the chosen strategy applies to all three levels.

The Components of Strategy

A well-articulated strategy summarizes two types of information. First, it provides contextual information of relevance to the future of the organization, including analysis of the implications of future developments. Second, it outlines the basic strategic choices made by the organization (see box, page 10) at the enterprise, corporate, and business levels, along with their rationales. Some of the items that I list below as major components of strategy relate mainly to contextual information, some to aspects of strategy, and some to both.

Clients and beneficiaries—A strategy should clearly identify the direct clients of the organization as well as the clients of the organization's clients. In the case of the international agricultural research organizations, the former typically include national agricultural research systems (NARSs) and the latter such groups as poor farmers.

Mere listing of future clients and beneficiaries by type and location is not sufficient. What is important is to determine the characteristics or aspects of the clients (the scientific research capabilities of NARSs, for example) that the organization would wish to influence or change through its own activities. Knowing the needs of its clients' clients often helps better define the needs of the organization's clients. For international agricultural research institutions, the strategy should reflect a good understanding of the circumstances contributing to the effectiveness of NARSs, so that through its future activities the international center can zero in on the factors that can provide the greatest leverage.

External environment—A strategy should describe a vision of the organization as it is expected to be in the future. Developing that vision requires an understanding of the likely future external environment of the organization and the opportunities and threats likely to be encountered in it.

Several aspects of the external environment are important. First, it is necessary to take into account the interests of the organization's major external stakeholders, that is, those who have a stake or interest in it. In the international agricultural research centers, stakeholder analysis should cover groups such as major donors, the CGIAR and its Technical Advisory Committee, other international centers with competing or complementary mandates, and the governmental and nongovernmental institutions in the major countries where the center operates.

Second, it is important to understand world or specific market trends in areas of interest to the organization. For agricultural research institutions, those include matters (such as trends in population and nutrition) that relate to the organization's beneficiaries as well as issues having to do with the physical, institutional, technological, and scientific environments.

Internal environment—An understanding of the organization's internal environment is necessary for formulating a strategy that builds on institutional strengths and overcomes weaknesses. Several aspects of the institution's internal environment are important and should be described and analyzed: 1) the interests of internal stakeholders (such as managers, staff, and members of the governing body); 2) the culture of the organization (commonly defined as shared patterns of values, beliefs, norms, and behaviors in an organization); and 3) the organization's past achievements and important competencies and limitations.

An organization's strategy describes the most desirable vision of its future, outlines the essential elements of a course it intends to follow to realize that vision, and provides a justification for the identified course.

Current strategy—An organization's future strategy should make reference to its current strategy and provide a rationale for changes, if any. The current strategy can be determined essentially in the same way as the future strategy. An organization's current strategy can be deduced from its past actions (Mintzberg and Waters 1985), regardless of whether the organization has followed a written strategic plan. The following criteria can be used in assessing the current strategy (Tilles 1963): evidence of impact; internal consistency with values and culture, competencies and resources, and organizational structure; external consistency with client needs, stakeholder interests, and other important aspects of the organization's environment; and appropriateness of the time horizon of the strategy.

Mission—A strategy needs to state clearly the mission of the organization, that is, why it exists and what goals it should pursue. This reflects the vision of the organization's leadership about where the institution should be headed in the future.

The organization's formal, constitutional mandate often defines the constraints and parameters within which the institution is expected to function. The mission spelled out in the strategy, on the other hand, serves as the operational mandate for the period under consideration. Conflicts between the formal mandate and the mission need to be resolved by introducing changes in one or the other.

Guiding values—A strategy clarifies and reinforces the institution's guiding values, which reflect the business philosophy of the organization and illustrate the broad principles to which it subscribes. They serve as a guide to operations and can be used as criteria in making strategic choices. Incongruities between the present culture of the organization and the guiding values selected for the future require cultural change. This is one of the least understood aspects of organizational change and one for which there are no "cookbook" solutions (Kilmann, Saxton, and Serpa 1985; Tichy 1983; Deal and Kennedy 1982).

Guiding values typically cover areas such as how the organization relates to its clients, other external stakeholders, and its staff and its views on risk taking and use of resources. The exact content of what might be referred to as an organization's "value map" will, of course, depend on its specific circumstances.

Key Questions in Strategic Planning

- Which of our future clients' needs can we meet?
- What are the implications for our future direction and plans of the external environment as it is likely to be in the future?
- What are the implications of our internal strengths and weaknesses for our future work?
- How effective is our current strategy?
- What should be our future mission?
- What should be our guiding values and business philosophy?
- What businesses should we be in, and what goals should we pursue in each?
- What are the major strategic issues confronting us, and what choices do we need to make about our future direction?
- How should we assign priorities to our business areas and subareas?
- What are the major operational implications of our future strategy, particularly for financing, staffing, infrastructure, and organizational structure?

Business areas—The term *business* refers here to the major strategic areas in which the organization wishes to work. Those are normally specified in the formal mandate and the mission statement.

The criteria for defining business areas relate mainly to aspects of the organization's environment, not its internal structure. Categories of clients or their needs, geography, or type of product/service are commonly used as criteria (Hanna 1985). Most international agricultural research institutions have two major businesses: research and strengthening NARSs. The former can be partitioned into smaller businesses such as germplasm development and crop management and the latter into improving research capabilities of NARSs and meeting their information needs. Those need not correspond to the organization's existing departments or units.

Partitioning larger businesses into smaller ones is necessary because the organization may wish to follow a distinctly different course in each business. Strategic issues relevant to the institution's training business, for example, would be different from those relating to its germplasm development activities.

A strategy identifies both the business areas in which the organization should work and also the goals to be pursued and the direction to be followed in each business. Business area goals should be derived from and substantively linked with the organization's overall mission.

Strategic issues—These are fundamental policy questions about directional choices the organization needs to make. A strategic issue often reflects a current or forthcoming development, inside or outside the organization, that has some bearing on what the organization should do and how. Strategic issues often relate to the major strengths and weaknesses of the organization and the threats and opportunities it faces (Ansoff 1980; Bryson 1987).

Analysis of strategic issues is the "guts" of a strategy. For that process determines the courses to be followed by an organization in accomplishing its overall mission and business area goals. Analysis of the needs of clients and beneficiaries, assessment of the internal and external environment, and evaluation of the current strategy all lead to identification of the major issues to be addressed by the strategy.

Examples of strategic issues currently confronting international agricultural research institutions include: the balance between basic and applied research, ways of addressing sustainability concerns, modes of collaboration with NARSs, general versus specialized training, centralization versus decentralization of activities, and ways of financing the implementation of the strategy.

Priorities—A strategy needs to reflect corporate-level choices, which is to say the relative priorities assigned to major business areas and subareas. This is often expressed in terms of planned flow of financial or human resources (or both) to business areas over time. The rationale for the chosen resource allocation pattern also needs to be spelled out in the strategy or its supporting documents.

Operational implications—A strategy represents a scenario for moving the organization from its present state to a desired future state (Egan, in press). But though it may provide an overall framework for guiding the organization, the strategic plan is several steps away from action. The courses and directions laid out in the strategy need to be operationalized to set the stage for their implementation. This is usually referred to as operational or program planning. The focus of an operational plan is on action plans and budgets. It translates the business area goals and strategies contained in the strategic plan into programs and projects with shorter term objectives.

There is no universal rule for differentiating strategic from operational or "tactical" concerns. Strategies cannot be formulated without taking into account their implementation, and some degree of overlap between the strategic and operational plans is both unavoidable and desirable. A change scenario that focuses only on the business aspects of the organization would be incomplete without reference to implications of the strategy for other institutional changes (in organizational structure, staffing mix, and physical infrastructure, for example). A strategy should draw only the broad outlines of the changes planned in those areas.

The strategic plan, which provides the starting point for the process of institutional change, takes into account operational considerations, even in the absence of an operational plan. The operational plan follows from the strategy but covers a shorter period than the strategic plan. In the private sector, strategic plans usually have a perspective of about five years, and the operational plans are prepared annually. Most of the centers within the CGIAR system prepare strategic plans with a 10- to 15-year perspective. Two kinds of center operational plans are prepared in the CGIAR: a medium-term program covering a five-year period and an annual program budget.

Finally, monitoring and control systems must be established to help assess results and contribute to reformulation of the strategic and operational plans (Below, Morrisey, and Acomb 1987; Morrisey, Below, and Acomb 1988). Those systems should be designed to generate the information needed to gauge performance at the institution, program, unit and individual levels and to determine the implications for the organization of trends and developments in the external environment.

A strategic issue often reflects a current or forthcoming development, inside or outside the organization, that has some bearing on what the organization should do and how.

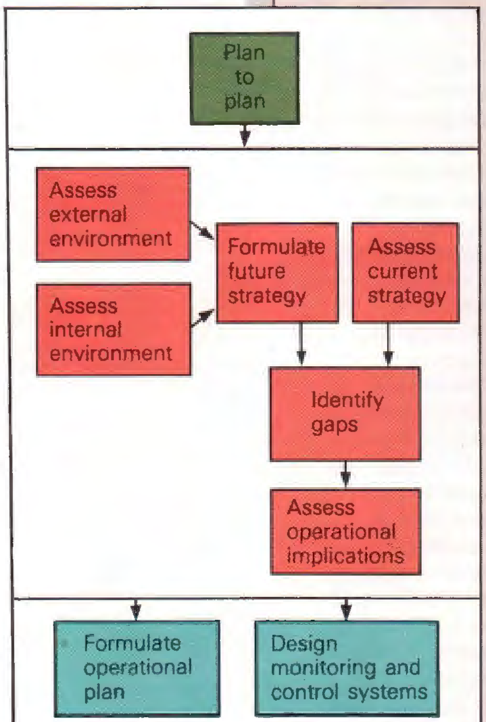
A Strategic Planning Process Model

In the final analysis, what matters for an organization is the content of the strategy, not the process used to formulate it. On the other hand, the process can serve purposes other than producing a plan, and one process may be more efficient than another. Because strategic planning is as much a crafting exercise as it is straightforward planning (Mintzberg 1987), no single process is likely to suit the needs of all organizations.

Several process models may be suitable for research organizations, including those developed by Below, Morrisey, and Acomb (1987) and Pfeiffer, Goodstein, and Nolan (1985), or a third developed specifically for public and nonprofit organizations (Bryson 1987). The model I advocate (see figure) can be summarized as follows.

Plan to plan—All the organizations I have worked with on strategic planning have found it useful to establish a strategic planning team (SPT) from within the organization. The SPT usually includes top management plus other key staff and should be led by the chief executive officer. Its size can vary, but inefficiencies begin creeping in when it exceeds 12.

It is useful for the SPT to go through a two- to three-day seminar and brainstorming session on strategic planning, with the help of an external consultant. This session should aim at sensitizing the group to the concepts, rationale, and processes of strategic planning and at establishing a common framework. The key tangible output of this task is an organizational structure (including subcommittees and task forces) and an action plan for formulating the strategic plan. An important intangible output is commitment of the members of the SPT to strategic planning and the roles they would play in implementing the action plan.



A strategic planning process model.

Formulate future strategy—I favor an iterative, zero-base approach to strategy formulation by which in the first iteration the future strategy is formulated without reference to the current strategy. This increases the chances that the plan will be future driven.

It is also useful for the SPT to consult widely with external groups, such as representatives of the clients, in the formulation of future strategy. Another is a group of outside experts who are knowledgeable about likely future developments in the organization's businesses and about the strategic issues that should be analyzed. Internal consultation with staff not involved in planning is also essential, although this often increases pressure to maintain the status quo.

Assess current strategy—This is particularly important for organizations with no written strategy or monitoring/control system for assessing the implementation of the strategy.

Identify gaps—Analysis of the differences between the current strategy and the first formulation of the future strategy helps identify major strategic changes, so that their organizational and operational implications can be studied.

Assess operational implications—The SPT should study the major strategic changes identified in terms of their implications for financing, staffing, physical facilities, and structural and cultural changes in the organization. Those findings often lead to a reconsideration of the future strategy.

Formulate operational plan and design monitoring and control systems—The monitoring and control system needs to address operational as well as strategic concerns. This would make the strategy a "living" document and alert the organization early on when there is need to reconsider the strategy in use.

Those, then, are the major components that should be included in a strategic plan, regardless of the exact procedure by which it is prepared (see box). In any case the process of strategic planning should be integrated in the sense that each component influences every other, and it should be viewed, from the management standpoint, as one link in an integrated institutional planning process.

Conclusions

One of the most important challenges facing research institutions is to find ways of encouraging strategic thinking at all levels of the organization. For organizations that have not gone through the experience, strategic planning helps initiate and motivate strategic thinking. This initial impetus should be reinforced and sustained by encouragement of continuous strategic analysis throughout the organization. Supporting the preparation of unit strategic plans can help instill organization-wide strategic thinking.

Formulating a strategic plan is costly, so extreme care should be taken to choose a planning process that avoids overplanning. Most decision makers are interested only in the main lines of an organization's strategy. Lengthy strategic plans often confuse the readers and could do more harm than good to the organization.

One of the purposes of strategic planning is to clarify and simplify why an organization exists and what would make it successful. This does not require the creation of a large planning bureaucracy and the preparation of thick planning manuals. The guiding members of an organization, that is, those responsible for developing a vision of its future, should be seen as its key strategic planners.

CIMMYT and several other international agricultural research institutions are currently engaged in formulating strategic and operational plans. As the experiences of the centers is unique among nonprofit international organizations, taking stock of the lessons learned will add to our current knowledge on planning.

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In the final analysis, what matters for an organization is the content of the strategy, not the process used to formulate it.

A Review of CIMMYT Programs

Prior to and during the strategic planning process in which CIMMYT was engaged this year, staff of our three research programs (Maize, Wheat, and Economics) debated intensely a whole range of issues. The crop improvement programs gave particular attention to two of them. First, what germplasm products will be required by our clients in national programs toward the year 2000? And second, what strategies will best enable us to develop and deliver those products in a timely and efficient manner? At the end of 1987, the strategic planning process was far from complete, and the jury was still out on those and other important questions.

Nevertheless, it seemed apparent that certain themes—chiefly the growing complexity of national agricultural research programs and their consequent need for a wider range of germplasm products—would figure importantly in the strategic plan and shape the future development of CIMMYT's crop programs. That outcome implies a reaffirmation of many of the Center's current policies and approaches—such as our emphasis on *intermediate* products and use of the *mega-environments* concept in priority setting (see explanations of these terms below)—but it also calls for some adjustments, aimed primarily at increasing the flexibility of the Maize and Wheat Programs in the choice of breeding objectives, materials, and strategies.

H.S. Dhaliwal, visiting scientist from Punjab, India (right), discusses new discoveries about Karnal bunt with W.C. James, CIMMYT's deputy director general for research.

Many of the issues that Economics Program staff were called upon to address also reflect changes anticipated in national agricultural research systems (NARSs) and in the global maize and wheat economies over the next decade or more. Certainly they impinge on research already underway, both within and outside the Program. For example, growth in resources committed to agricultural research will not be as rapid as in the past, and the economic environments in which research is conducted will become increasingly volatile. In such a context, the Program's efforts to monitor long-term trends in the world wheat and maize economies and the policy environment influencing them may assume greater importance. As the implications of that and other issues are better articulated in the course of strategic planning, the emphasis on certain areas of work relative to others will undoubtedly change.

A Global Research and Training Program

The theme of this *Annual Report*, however, is the process of planning for change, not its outcome, and the maize, wheat, and economics reports that follow focus more on the present than on the future. The products and services described in those reports are of the following main types:

- Improved germplasm for major production environments in the Third World, with emphasis on the less favored ones
- New procedures or modifications in existing ones for plant breeding, crop management, and economics research
- Training for agricultural scientists in developing countries
- Consultation and assistance for national agricultural research programs
- Scientific information developed in connection with all of the above products and services

The main recipients of our products and services are national programs, which combine their own resources with CIMMYT's contributions to develop improved agricultural technology for farmers. Our experience is that such innovations can boost the productivity of farmers' resources, thereby enabling them to increase farm income. Increased productivity at the farm level is no doubt accompanied by greater production nationwide, but its chief benefit is to help alleviate poverty and generate income for development.

The Center's products and services are provided by a total of about 120 scientific staff working in three research programs and various research service units. Roughly half of the scientific staff of the crop improvement programs and a greater proportion of Economics Program staff work at 20 locations around the world (see map), while the rest are stationed at our headquarters in Mexico. The latter group is ably assisted by a support staff of about 850 people.

Most of the scientific staff at headquarters are engaged in germplasm development or related research. That work is carried out, with assistance from laboratory and experiment station staff, at five locations in Mexico (Ciudad Obregón, El Batán, Poza Rica, Tlaltizapán, and Toluca), representing a range of maize and wheat production environments found in developing countries. Those sites and farmers' fields nearby are the loci of our Mexico-based training programs as well.

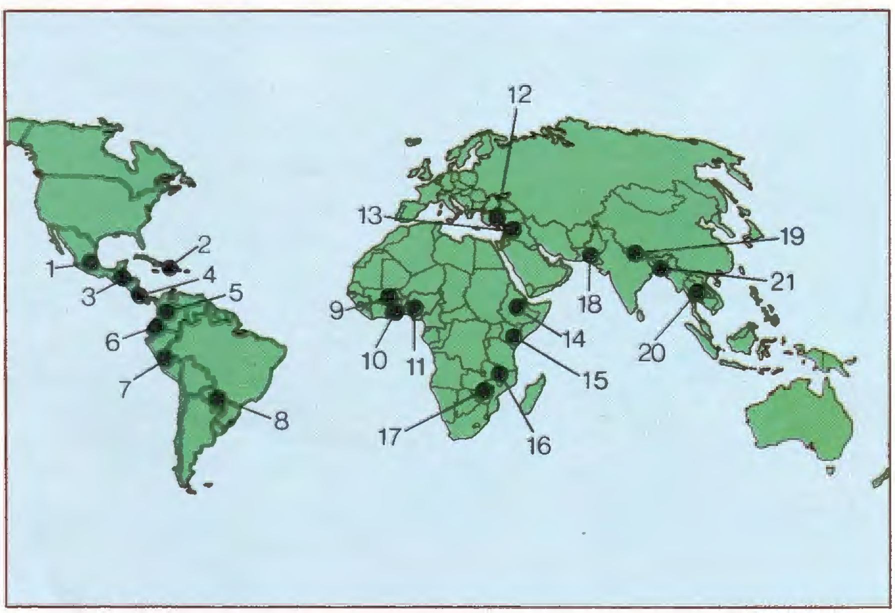
Some of CIMMYT's crop improvement work, most of its economics research, and a large part of its training and other assistance to national programs take place in maize, wheat, and economics regional operations and bilateral projects. Although the "outreach" activities of the three programs share a common basis (mainly the cost effectiveness of international cooperation in agricultural research), they differ somewhat in style and emphasis, as becomes apparent in reports that follow.

Intermediate Products for Crop Mega-Environments

In general, the germplasm developed by CIMMYT and disseminated through its international testing networks consists of intermediate products. That emphasis and a concept we term mega-environments are made necessary by the global character of our research programs and serve the interests of our clients better than other options. We use the term intermediate for refined germplasm that is broadly adapted within mega-environments, which are globally dispersed areas distinguished from one another by differences in availability of moisture, incidence of biotic and abiotic stresses, and other features that give them fairly distinct and uniform germplasm requirements.

Using the germplasm and often other products and services we provide, national programs develop final germplasm products (finished varieties and hybrids) for particular crop production areas within the mega-environments represented in their countries. That step may be large or small, depending on the capacity of the national program. The less developed ones will tend to release CIMMYT materials in much the same form in which they receive them, after a few seasons of experiment station and on-farm testing, whereas the more advanced programs will introduce our germplasm into breeding nurseries, where it undergoes further selection and can be used in various ways. But in any case, we are convinced that, by leaving the step of final product development largely to national programs, we have helped to widen the availability of improved maize and wheat to farmers and strengthened the research capabilities of many Third World countries.

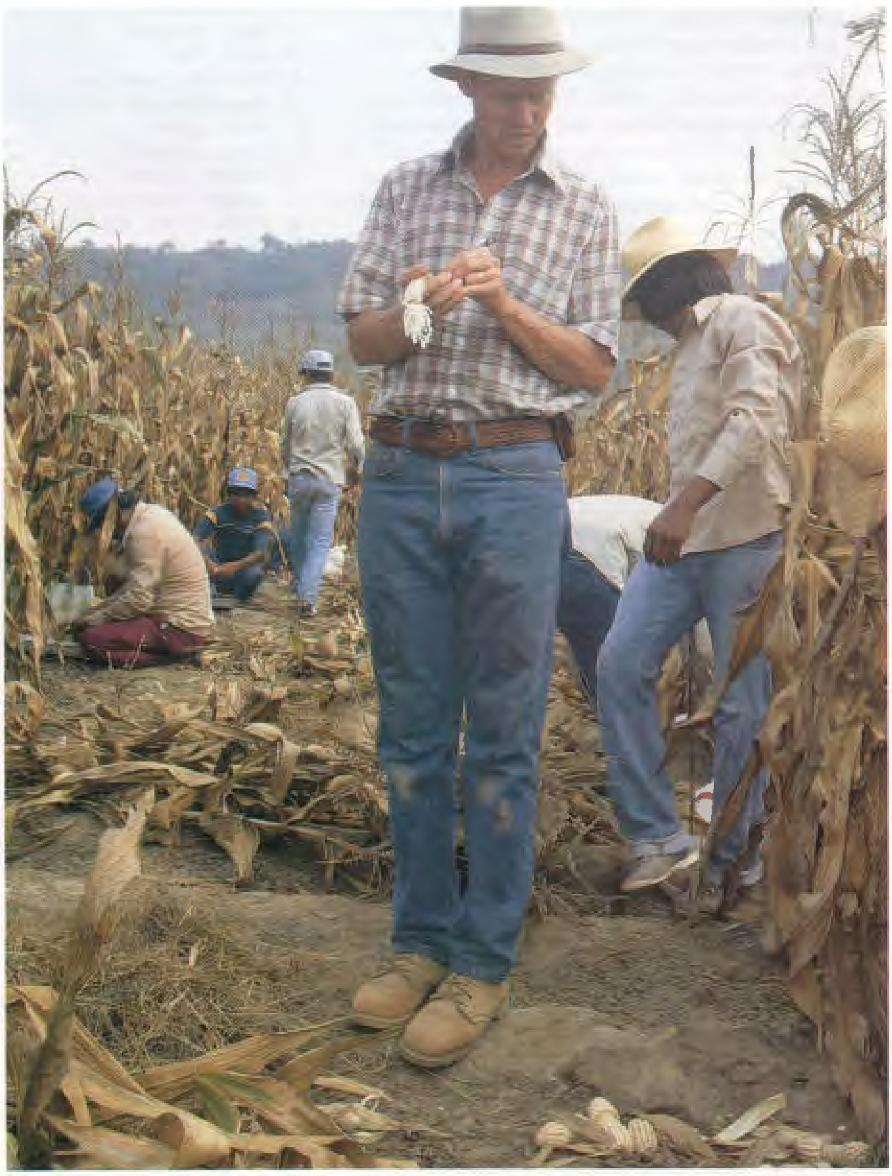
1. El Batán, Mexico
2. Les Cayes, Haiti
3. Guatemala City, Guatemala
4. San José, Costa Rica
5. Cali, Colombia
6. Quito, Ecuador
7. Lima, Peru
8. Asunción, Paraguay
9. Ouagadougou, Burkina Faso
10. Accra, Ghana
11. Ibadan, Nigeria
12. Ankara, Turkey
13. Aleppo, Syria
14. Addis Ababa, Ethiopia
15. Nairobi, Kenya
16. Lilongwe, Malawi
17. Harare, Zimbabwe
18. Islamabad, Pakistan
19. Kathmandu, Nepal
20. Bangkok, Thailand
21. Dhaka, Bangladesh



Locations at which CIMMYT staff are based.

Maize Research

As strategic planning got underway this year at CIMMYT, certain trends were already developing in the Maize Program that seem quite compatible with the major themes emerging from the planning process, chiefly that of flexibility in the breeding programs. As indicated in the following reports on germplasm development and related research and on support to national programs, new activities are being initiated and old ones modified across the Maize Program (see box, pages 28-29, on its activities and organization) to develop a broader array of germplasm products by means of various breeding approaches.



Development and Distribution of Germplasm

The formation of some new germplasm complexes, shifts in priorities, and extensive evaluations of materials and methods suggest something of the predominant character of our breeding program in 1987. If some of those activities seem a little tentative and exploratory, it is because we are in the process of sharpening our perceptions of clients' needs and of finding ways to make our breeding program conform more closely to them.

Gene pool development and improvement—Last year we took steps to enlarge the contribution of the gene pools to our overall germplasm improvement effort. The main ones were to create and refine the concepts of general- and special-purpose pools (see definitions in box, page 28) and to adjust breeding priorities based partly on the results of a recent CIMMYT study of maize mega-environments. In 1987 the development of some special-purpose materials was initiated; new activities were undertaken with the existing general-purpose pools; and additional staff were assigned to this work in anticipation that it will soon occupy a much more central place in the Program than it has before.

There is a great need in many developing countries for improved early maturing tropical materials but relatively few sources of them. To expand the range of products available, we began a thorough search in 1987 for germplasm to be used in the formation of new early maturing pools and started applying more intensive selection procedures to the ones already developed.

Since a large portion of the Third World's early maturing tropical maize is grown in marginal environments, we are giving heavy emphasis to stress tolerance, particularly drought. Families from the early, white dent Pool 16 were evaluated under drought and high plant density, and a new cycle of the pool, along with several synthetics, have been formed on the basis of criteria that may enable us to identify genotypes that perform well under low moisture. Similar procedures are being applied to early generation lines from early maturing, yellow-grain germplasm. In those and other early materials, we will emphasize (in addition to drought tolerance) resistances to lodging,

The Maize Program conducted several studies in 1987 to generate new information about its elite materials that will assist national program cooperators in making seed requests. Here breeder Dana Eaton evaluates harvested ears in a trial at CIMMYT's Poza Rica experiment station.

diseases, and insects, traits that should contribute to the yield stability of the germplasm in marginal environments.

Among late-maturing tropical materials, we began forming a special-purpose pool that will serve as a source of the erect leaf type. It should help breeders to capitalize on the well-known observations that erect leaves enable maize plants to utilize sunlight more efficiently and contribute to drought tolerance. Development of a tropical borer-resistance pool was also initiated with a selected fraction (families showing a high level of resistance and reasonably good adaptation to tropical environments) from a multiple-borer-resistance (MBR) pool developed by the entomology unit. In preparation for developing other special-purpose pools, we began a systematic search of CIMMYT's late-maturing tropical germplasm for sources of various resistances, particularly to ear and stalk rots.

In the work on general-purpose, late-maturing tropical pools, we sharpened our breeding objectives and refined the methods employed so as to select more efficiently among families. Two of the pools are being improved for fall armyworm (*Spodoptera frugiperda*) resistance, using an S2 selection scheme. With the other three late pools, we are applying an alternating half-sib and S1 selection scheme and placing increased emphasis on resistance to southern leaf blight (*Helminthosporium maydis*). New late tropical white dent and yellow flint pools are being formed and could eventually replace their predecessors if they are found to be superior.

At the request of staff in Zimbabwe, we started evaluating some new sources of resistance to ear rots and will later form a subtropical pool source of this trait. In an effort to overcome one drawback of the general-purpose subtropical pools, we continued developing new versions of them and are selecting intensively for resistance to northern leaf blight (*Helminthosporium turcicum*), which is a serious problem throughout the subtropics. Results of a preliminary evaluation indicate that good progress has been made in the improvement of resistance and that these gains have not been won at the expense of yield potential. In fact, one pool out of four selected for resistance showed yield improvement in the absence of *H. turcicum* infection.

Recent changes of priorities in the work on tropical and subtropical pools are based to a large degree on the results of the mega-environments study mentioned above.

Population improvement and international testing—During 1987 we were occupied in handling the Maize Program's advanced populations, generating experimental varieties, and increasing seed. In the course of that work, we continued placing heavy selection pressure on the subtropical populations for resistance to *H. turcicum* and observed a marked increase in resistance as a result of selection over the last few years. We also evaluated a number of materials for progress through selection for resistance to tar spot (*Phyllachora maydis*), work that was started in conjunction with the pathology unit during 1986 (see box, page 18).

The formation of some new germplasm complexes, shifts in priorities, and extensive evaluations of materials and methods suggest the predominant character of our maize breeding program in 1987.

In considering a reduction in our total number of advanced populations, we consulted with staff in the regional programs and examined results of the mega-environments study. Populations for which there no longer seems to be much demand will be shelved next year to free up resources for intensifying our work with the remaining materials and for developing some new ones. As a prelude to those efforts, we conducted several studies to evaluate our breeding materials and selection techniques.

The results of one study underscore the importance of the actual performance, compared with the sometimes deceptive appearance, of the maize plant as a criterion for selection. In topcrossing S1 families from several populations onto other materials at our station in Tlaltizapán, we noted that many of the families exhibited yellowing and poorer agronomic type than the others. Those symptoms are commonly observed at Tlaltizapán, and families showing them are routinely discarded. It occurred to us, however, that families with yellowing plants may simply have been responding to certain soil characteristics at that site and would yield as well as the rest of the population at other locations having better soil conditions. Upon testing that hypothesis in multilocational trials, we found that there were essentially no differences in grain yield between the yellow and normal entries.

Other studies were intended to generate new information about the elite materials currently available in the Maize Program. One of those was aimed at quantifying the levels of disease resistances and genetic variability for such traits within the populations and across all of the elite germplasm that we are handling. The results will enable us to offer more precise information to cooperators requesting our germplasm.

Symptom development of the tarspot complex: 1) tarspot resulting from infection by *Phyllachora maydis*, 2) tarspot surrounded by an oval necrotic area, indicating the presence of *P. maydis* and subsequent infection by *Monographella maydis*, 3) round, smaller necrotic area possibly resulting from infection by a third, as yet unidentified, pathogen (the spot in this case is the pycnidia of the third pathogen), and 4) large blighted area forming as necrotic spots merge.

Targetting Tar Spot

The tar spot complex was first noticed at our Poza Rica experiment station in the late 1970s but was not considered to be very important (although it was present) in farmers' fields. Since then, however, it has been observed to cause severe damage in parts of Mexico and in several Central American countries. The Maize Program's response to that development has been twofold, consisting of 1) epidemiological studies and related work on the disease complex and 2) efforts to develop resistant germplasm and other control measures.

Development of the Disease Complex

The findings of the epidemiological study (which is being funded by the government of West Germany through a grant to the University of Giessen) indicate that development of the complex results from an interaction of climatic factors and two or more fungal pathogens. Two pathogens have been reported in the scientific literature: *Phyllachora maydis* and its asexual stage *Linochora*, along with *Monographella maydis* and its asexual stage *Microdochium*. The first fungal species causes the typical tarspot symptoms shown in the accompanying photograph, which probably result in only a slight reduction of grain yield. Much more serious damage to leaf tissue occurs, however, when lesions caused by *P. maydis* are invaded by *M. maydis* and the two pathogens act in concert to cause the destructive tarspot complex. The close association between those two is sometimes joined by another pathogen, which was identified in the course of our studies. This third fungus, which occasionally occurs on about one-third of the leaf area affected by the disease, will be named and reported in the near future.

The results of a survey at 30 locations in Mexico indicate that the tarspot complex occurs most commonly between 1300 and 2300 masl in subtropical and transitional regions characterized by cool temperatures (a monthly average of 16°-18°C), high rainfall, and frequent fog. But it also occurs in the lowland tropics (the environment represented by Poza Rica), being particularly severe during the winter season. The disease complex is thus not associated so much with a particular elevation range as with the cool, humid conditions required for disease development during the period just before flowering until near maturity. In our experiments the disease was found to cause crop losses of up to 30%, although earlier and more severe disease development has occurred in other seasons and other locations. Other studies have shown that disease severity increases under high soil nitrogen application.

Selection for Resistance

The Maize Program's primary strategy for remedying this problem is to develop host resistance by conducting half-sib recurrent selection in two groups of materials (white and yellow grain) that include lines selected by our hybrid program for tar spot resistance and experimental varieties from various populations. The two materials being selected perform well in tropical and subtropical areas; the yellow population, for example, is a component of some hybrids in Mexico's subtropical Bajío region. After one cycle of selection, the populations showed good improvement both in yield and tar spot resistance. As more resistant germplasm is developed, we will determine the genetic components of resistance to improve the efficiency of future selection. Our second control strategy is to use fungicides. In a trial completed in 1987, we determined which chemicals are most effective in controlling the disease.

Another study was initiated to better predict the maturity of our advanced populations in diverse environments. Traditionally, germplasm maturity has been measured in days from planting to flowering. The drawback of that practice is that, when a given material is grown in different environments with differing temperature regimes, its maturity may vary drastically from one environment to another. To avoid the relativity inherent in that way of expressing maturity, we calculated the heat units to flowering and physiological maturity of all of the populations. That information will be made available to our cooperators, who can then determine the number of heat units in their growing seasons and, using that information and our data on disease resistance, choose materials for their own maize programs with much greater precision.

No major changes took place during 1987 in the structure of international testing, which is a critical part of our maize improvement effort and our chief means of distributing germplasm to researchers in national programs (see appendix, page 78). Nevertheless, it became more evident this year that we will soon need additional types of trials for preliminary testing of progeny and varieties.

Collection of initial information for the maize mega-environments study mentioned in various sections of this report was completed in 1987. We have compiled data on all 64 countries included in the study, identified some 34 mega-environments worldwide, and determined both the number of countries and extent of the area representing each mega-environment. Obviously, the CIMMYT Maize Program will not be able to develop germplasm for all of those environments but will have to group them and assign priorities to them based in large part on the extent of the maize area that each contains. We will also continually update and improve our estimates of various features of developing country maize production and revise our definitions of the mega-environments accordingly.

In a related study, we received agroclimatic data from 178 experiment stations involved in the international maize testing network. That information will enable us to group the test sites in analyzing trial results and eventually to improve testing efficiency and conduct more meaningful data analysis.

Highland maize—This is one of two classes of maize (the other being quality protein maize) that, because of their special character, are handled in separate systems from those for other materials. In 1987 the highland maize program continued refining definitions of the world's highland mega-environments and made significant advances in developing improved germplasm for them.

The former task is made somewhat difficult by varying usage of the term *highland*. In India, for example, the lower end of the elevation range thought to encompass highlands is only 1000 masl, compared to 1500 in eastern and southern Africa and 2000 in Latin America. Clearly, we cannot characterize highlands on the basis of elevation alone but will need additional information on climatic factors, including average frost dates and temperatures. In clarifying our definitions of the highlands, we will give particular attention to Africa and Asia, whose highland production is still less familiar to us than that of the Americas.

In the meantime we are developing diverse materials representing a wide range of adaptation, from which breeders in national programs can select germplasm that is well suited to their own highland environments. Their choices and the performance of the materials in general should provide us with much new information about the germplasm requirements of highland production worldwide.

The program currently has six gene pools that have undergone several cycles of improvement. For most of the pools, we also have corresponding advanced populations, which are the result of crossing the pools (consisting largely of Mexican germplasm) with exotic materials. The purposes of those crosses were to eliminate the tillering trait of the Mexican materials, improve their resistance to root lodging as well as their plant type and stress tolerance, and to broaden their genetic base. Once the plant type of the populations has been improved sufficiently, with minimum loss of cold tolerance and other useful traits in the Mexican germplasm, the pools will be discontinued. The last several years have been quite favorable for selection for yield and resistance or tolerance to various stresses in the populations. In 1985 ear rot infection was very severe; in 1986 favorable growing conditions promoted high yields; and in 1987 both drought and early frost occurred, and the incidence of lodging was high in susceptible families.

New information about the maturity and disease resistances of our elite germplasm will enable cooperators to choose materials for their own programs with much greater precision.

Preliminary trials of experimental varieties from the populations were conducted this year at El Batán and other locations. Testing of the late-maturing varieties was inconclusive, with no significant differences in grain yield between the entries. All of the early maturing varieties, however, yielded significantly more than the check hybrid at El Batán. They also performed better than the checks in all except one off-station trial. Partly on the basis of those preliminary findings, we prepared 30 sets of Experimental Variety Trial (EVT) 17, which includes a range of experimental varieties, some for the tropical highlands, others for the transition zone (between midaltitude and highland), and still others for temperate highlands. Our announcement of that trial, which has not been sent out since 1978, drew 50 requests from breeders in national programs, indicating considerable pent up demand for highland maize with a semident grain type.

Highland maize breeder James Lothrop examining ears harvested from yield trials at CIMMYT headquarters. From the wide range of materials developed by the highland program, breeders in developing countries will be able to select germplasm that is well suited to their own highland environments.

Quality protein maize—As suggested in last year's annual report, the work on QPM is at a crossroads. We have developed a sizeable collection of this special class of germplasm, but the demand for it continues to be relatively low. Rather than continue handling sizeable numbers of QPM pools and populations, an approach that has brought this material a long way from the numerous problems that plagued its opaque-2 predecessors, we are going in a somewhat different direction, with the intention of identifying suitable product niches for QPM in developing country maize production.

The results of a trial conducted in 1987 indicate that some QPM tropical populations yield as well as or better than their normal counterparts. Upon the strength of those findings, we are now considering how and where to examine more fully the materials' yield potential and utility in the improvement of human and animal nutrition (with special emphasis on their use in animal feed). Given our limited resources, it will clearly be necessary to concentrate on just a few selected countries, a possibility we began to investigate late in 1986 and continued to explore this year in conjunction with regional staff. A second requirement imposed on us by resource constraints is to reduce and consolidate the array of QPM germplasm in the Program, tasks that we began in 1987 by retiring the pools from half-sib selection.

Eventually, we will cut back population improvement as well and intensify development of inbred lines from the best QPM materials, a strategy that offers several important advantages. First, in the production of QPM hybrid seed from inbreds, the possibility of contamination by normal maize (and with it the loss of improved protein quality) will be much reduced, since pollination is strictly controlled during hybrid seed production. Second, from the QPM inbreds, we will be able to develop a wide range of products (including various types of hybrids as well as synthetics that can be used as open-pollinated varieties) and readily identify high-performance genotypes for specific environments. And third, we can probably reduce the size of the program and its consumption of resources. Various aspects of that strategy (notably the development of final product hybrids for only a few countries) represent a wide deviation from policies to which we adhere quite closely in breeding normal maize. But then again QPM is a special case requiring what for CIMMYT is an unusual approach.

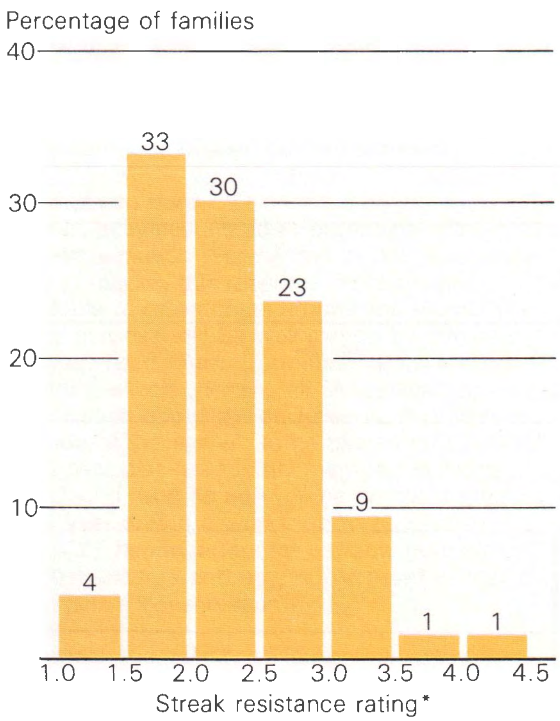
CIMMYT/IITA breeding program in Africa—At IITA headquarters in Nigeria, Maize Program staff continued with two breeding projects initiated during the early 1980s, one involving conversion of varieties to maize streak resistance through backcrossing and the other improvement of the population La Posta for resistance to this disease. In the former, 10 varieties were advanced to the fifth or sixth backcross and recombined for testing and distribution next year. Many new materials were received from Nigeria and Benin for conversion to streak resistance and were crossed to donors of this trait. Families of La Posta, which in its seventh cycle of selection continues to show a high degree of streak resistance (see figure), were regenerated for distribution in a progeny trial early next year, and seven experimental varieties were formed for evaluation in an EVT.

At the University of Zimbabwe, establishment of a midaltitude maize research station was essentially completed in 1987, including development of facilities for rearing leafhoppers (*Cicadulina mbila*), the insect vector of maize streak virus. The primary objectives of the breeding strategy being employed there are to 1) facilitate reciprocal exchange of midaltitude germplasm, 2) increase the stock of available elite germplasm for midaltitude ecologies, and 3) incorporate into the germplasm traits whose absence limits its performance.

In many respects this strategy reflects the growing trend in the Maize Program toward a greater diversity of products and breeding methods as well as a more rapid influx into the improvement process of new materials, which are to be evaluated and then exploited or discarded. The scheme being implemented at the midaltitude station begins with the formation of many narrow-based populations through an extensive crossing program in which the pedigrees of all populations are recorded. Then follows a series of evaluations and cycles of recurrent selection, leading eventually to the development of various products, mainly breeding populations, inbred families, and streak-resistant conversions of the midaltitude germplasm that is already available.

Support of Germplasm Development

As in any sizeable breeding program, maize improvement at CIMMYT is supported by a team of specialists in various fields, who provide services that are critical to effective selection (such as artificial disease infection and selection indices) and conduct basic studies that increase our understanding of biotic and abiotic stresses and provide new insights into the development of resistant germplasm. Unlike their colleagues in many other breeding programs, however, our entomologists, pathologists, and physiologists also devote a considerable share of their time to the development of germplasm that can be employed by our own breeders and those in national programs as sources of stress resistance or tolerance.



* 1 = highly resistant and 5 = highly susceptible.

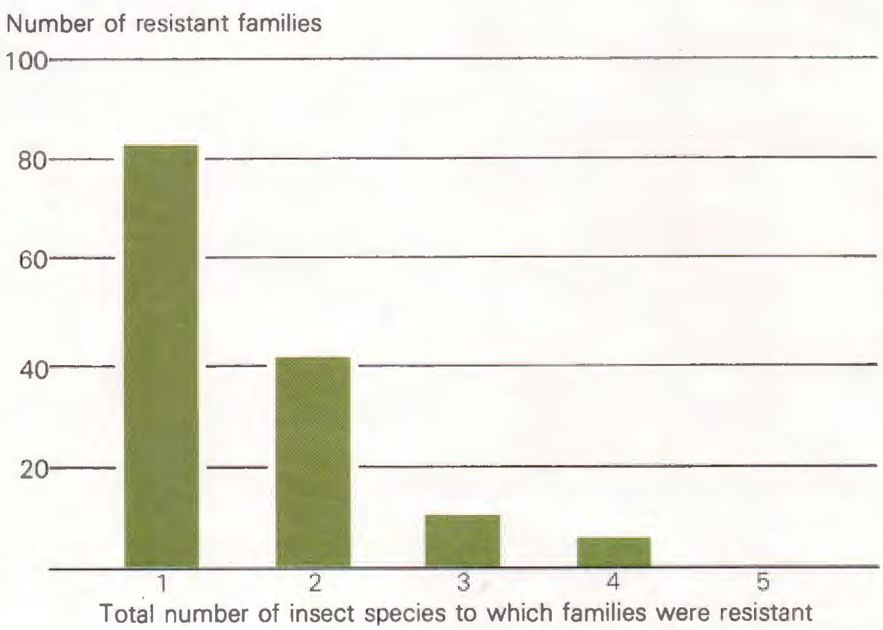
Frequency distribution of streak resistance among 227 S1 Progeny of La Posta (cycle 7) under induced streak pressure.

Pathology—As mentioned in preceding sections, good progress was made this year toward improving the resistance of the subtropical gene pools and populations to *H. turcicum* and the resistance to tar spot of selected tropical materials (see box, page 18). Respectable gains were also recorded in resistance to various other diseases (ear and stalk rots, leaf diseases, and so forth) in our tropical germplasm. So that breeders at CIMMYT and in national programs can have additional sources of disease resistance, we are developing several new materials, based largely on populations, varieties, and hybrids that are resistant to downy mildew. To improve the adaptation of those materials to maize-growing environments in Latin America, we are now selecting for resistance to various diseases that are prevalent there.

One of three populations that have been undergoing selection for downy mildew resistance in Thailand was returned to headquarters this year, where it will be further improved and distributed in international trials. Four populations (two in the Dominican Republic and the others in El Salvador) are being improved for resistance to corn stunt, caused by a spiroplasma, and are now in their second cycle of selection. Results of the first cycle are as follows:

	Yield gain (%)*	Stunt reduction (%)*
Dominican Republic		
Population 28	29.1	19.1
Population 36	27.4	31.7
El Salvador		
Population 22	43.3	26.4
Population 73	42.4	35.7

* The values given are means for two locations under natural stunt infection and indicate the percent difference between the selected families and population mean.



Number of families resistant (out of a total of 200) to one or more insect species in international testing of the multiple-borer-resistance pool (MBR).

Entomology—In 1987 we continued work begun in the mid-1980s on two insect-resistant pools and became involved in a new project on resistance to the grain weevil, which destroys a sizeable share of developing country farmers' maize yield in storage.

Seed of selected entries from progeny tests of the multiple-borer resistance (MBR) pool were received from locations in Kenya, Mexico, and the USA. A substantial proportion of the families showed promise as sources of resistance to single or multiple pest species (see figure). Based on family performance at the various sites, we are developing experimental varieties. Before regenerating progeny for a second round of testing in 1988, we are trying to incorporate into the MBR pool resistance to various diseases that are prevalent in the subtropics, so that it will be better adapted to test sites in that ecology. For the same reason, we are adding resistances to diseases that limit production in sub-Saharan Africa and Southeast Asia to the Multiple-Insect-Resistant Tropical (MIRT) pool. In addition, as new agronomically useful sources of resistance are identified, we are incorporating them into the MBR and MIRT pools. The agronomic performance of those materials will be critical to their successful exploitation in breeding programs.

To share some of the results of that work and to pull together a set of papers on the best techniques from some of the world's most accomplished programs, we held a conference in April on the development of host plant resistance to maize insects. The proceedings of that meeting should be available by late 1988.

The project on insect pests of stored maize derives from work of researchers at the University of Ottawa in Canada, who evaluated numerous maize gene pools, experimental varieties, and landraces obtained from CIMMYT and other sources for susceptibility to storage insects. They observed a substantial range in susceptibility among those materials, demonstrated the importance of phenolic compounds as factors in resistance, and suggested that these findings be used to develop selection criteria for resistance screening.

Subsequent investigations will be conducted by the University of Ottawa, CIMMYT, Mexico's National Polytechnic Institute, and the University of Zimbabwe with funding from the International Development Research Centre (IDRC) in Canada. The initial contribution of the Center's Maize Program will be to conduct experiment station and on-farm trials (the former begun at two stations late in 1987) to confirm the results of laboratory evaluations for resistance to storage pests.

Physiology—Drought tolerance continues to receive the bulk of our resources, but we are also conducting studies on nitrogen-use efficiency, the contribution of prolificacy to general stress tolerance, and the photoperiod sensitivity of CIMMYT's maize germplasm (the last in cooperation with the University of Reading in the UK).

This year we carried forward two approaches initiated in 1986 for developing drought-tolerant materials, one being the long-term formation of a drought pool and the other short-term improvement of four elite populations for drought tolerance (see *Research Highlights 1986* for details on the breeding methodologies). How we handle those materials in the future may be affected by the results of an evaluation completed in 1987 of cycles of selection in Tuxpeño Sequía (see box, page 24). Work on that population, initiated in 1975, was the point of departure for our program of recurrent selection in the four elite materials. Three other studies, completed or begun in 1987, may also provide information that will enable us to refine our selection techniques. The one completed this year involved examining the root systems of various materials by four different methods. In the second study, we are trying to ascertain the relative worth of erect leaves as a criterion in selecting for drought tolerance and in the third to show whether the use of a line-source sprinkler system offers an advantage over our current approach of selecting for tolerance under three distinct levels of drought stress. The attraction of the line-source system is that it creates a continuous gradient of drought stress across which we can examine the responses of various traits that we consider to be associated with tolerance.

In our work on nitrogen-use efficiency, two cycles of progeny selection had been completed by the end of 1987, and an evaluation of experimental varieties had been performed, all under high and low levels of nitrogen. Selections were made on the basis of various physiological traits (such as leaf chlorophyll content at flowering under low nitrogen) that show a high correlation with grain yield. The results continue to indicate, as did an initial evaluation of elite and landrace materials, that stress-tolerant genotypes can be identified most efficiently under nitrogen stress. To increase the precision of our selection procedure, we are using various statistical techniques (such as neighbor analysis) to minimize the influence of the extremely high soil variability we observe in our stressed nurseries.

The fourth cycle of selection in our four semiprolific pools was completed in 1987, and progress will be evaluated early next year under three different plant densities. The results will give us some indication of whether the general stress tolerance of the populations has been improved through selection for prolificacy under plant density stress.

Germplasm bank—This unit is engaged in various activities aimed at protecting the genetic variation represented in our accessions and at making this resource more readily available to researchers around the world. The latter purpose will be well served by our new computerized Maize Germplasm Bank Inquiry System, which contains all of the available information about the accessions. A prototype version of the system to be placed on CD-ROM (compact disc—read-only memory) is being developed, and its use will be demonstrated next year during a workshop to be held at CIMMYT headquarters for national germplasm bank managers and others interested in maize germplasm conservation.

To check the validity of the primary race classifications of landraces stored in the bank, we conducted trials at two sites in Mexico, the results of which generally coincided with the classifications made by previous bank managers. We also carried out evaluations of Caribbean materials as part of the Latin American Maize Project (LAMP), in which national programs evaluate their own maize

A substantial portion of families selected in Kenya, Mexico, and the USA showed promise as sources of resistance to single or multiple pest species.

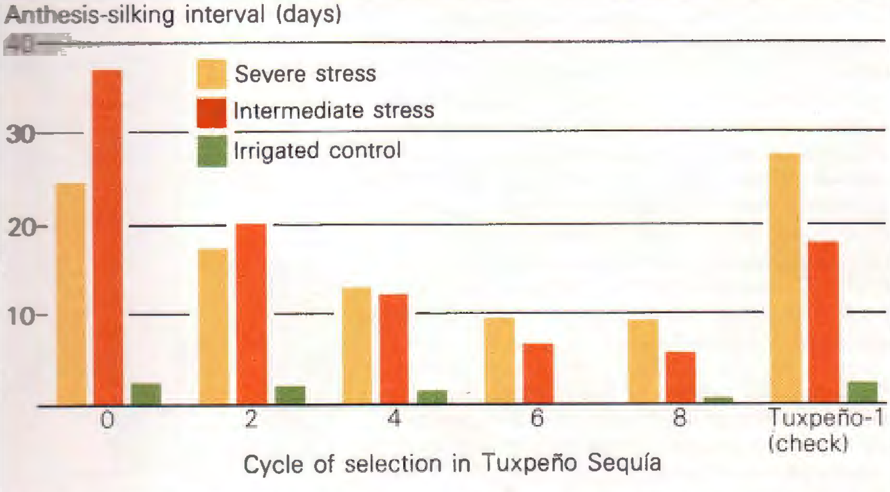
Progress Through Selection for Drought Tolerance

Between 1975 and 1985, the population Tuxpeño Sequía underwent recurrent selection for drought tolerance in a project that has been reported on in various CIMMYT publications. During 1987 the physiology unit conducted a study to determine physiological, morphological, and agronomic changes brought about in the population through selection.

Methods

During eight cycles of selection, full-sib families of the population were grown under three moisture treatments: 1) no stress (irrigated control), 2) intermediate stress (irrigation stopped two weeks before anthesis), and 3) severe stress (grown only on stored soil water after one irrigation at planting). Selections were made on the basis of a selection index that included grain yield under irrigation (to maintain yield potential) and grain yield under stress, along with various traits indicating the ability of the families to find water during drought, namely anthesis-silking interval (ASI) under stress, relative stem and leaf elongation rate under stress, canopy temperature under stress, and a score of leaf senescence. We also monitored anthesis date to ensure that the population did not become significantly earlier during selection.

During the dry season of 1987, cycles 0, 2, 4, 6, and 8 of Tuxpeño Sequía, plus Tuxpeño-1 as a check (representing six cycles of selection with international testing), were evaluated in a split-block design with four replications under three moisture regimes. The latter resembled those used in selection, but the stress levels were more severe. Data were taken on 12 traits indicating the performance of the population under various stress levels.



Changes in anthesis-silking interval over eight cycles of selection under three moisture regimes, as determined in a trial at Tlaltizapán, Mexico.

Results

The most striking result of the evaluation is that significant changes took place in ASI, while little or no progress was registered in other traits that were thought to be good indicators of drought tolerance or avoidance and for which selection pressure had been reasonably strong. At the outset of selection, the gap between anthesis and silking was so wide under both drought levels that most plants failed to produce ears. After eight cycles of selection, however, the ASI had been reduced from an average of 25 days under severe drought stress to 9.2 days (see figure).

The lack of progress in traits such as relative leaf and stem elongation rate may be the result of low heritability, in which case selection for them would not be very worthwhile. Another possibility, however, is that the effects of selection for those traits were obscured by the marked improvement in ASI, just as one would be hard pressed to note much change in a mild case of the flu in a patient being successfully treated for a life-threatening disease. With plants as with people, some problems must receive higher priority than others in the struggle to survive.

If the latter hypothesis is correct, then a more effective approach in selection for drought tolerance might be to improve the population for ASI first (ensuring that a large proportion of plants can produce ears under drought stress) and only then to select for other traits thought to improve plant performance under drought. Further studies will be carried out in 1988 to determine whether that hypothesis, which appears to hold for Tuxpeño Sequía, is also applicable to other populations. If so, we will modify our selection procedure for short-term improvement in the drought tolerance of elite maize germplasm, concentrating first on synchronization of flowering under stress and later on other drought-adaptive traits.

holdings and share the results with colleagues in other countries. The program is contributing significantly to the generation and distribution of new information about maize landraces and other materials.

The bank was engaged in several activities in 1987 that are intended to guarantee the safety of the materials we are conserving. Until this year one of those—regeneration of bank germplasm—was performed in cooperation with Pioneer Hi-Bred International, whose assistance in the work has been very helpful. But since the materials most urgently requiring regeneration have now been regenerated, this task will in the future be performed entirely by our own staff. In preparation for a more detailed study to be initiated next year on the effects of seed storage, a preliminary evaluation was made of seed drying rates and viability. We also followed up on a program initiated in 1985 for in situ monitoring of teosinte populations with a seed collection visit to the state of Jalisco, Mexico.

Wide crosses—This unit began preparing during 1987 to contribute in new ways to the Maize Program's germplasm development efforts, in addition to its continuing work on maize x *Tripsacum* crosses. Because of the affinity between that work and biotechnology research, the wide crosses unit will in the future devote a sizeable share of its time and effort to keeping Program staff informed about possibilities for applying tools developed through biotechnology to practical breeding programs. Toward that end the staff member in charge of the unit began a nine-month study leave at the University of Minnesota, where he will receive training and gain experience in the use of RFLPs (restriction fragment length polymorphisms) to bring about genetic improvement by screening for useful traits in the germplasm.

In his absence work on the tripsacoid population discussed in the *1986 Annual Report* was continued by other staff, and work proceeded on cytogenetic analysis in maize x *Tripsacum* hybrids and their progeny. The purpose of the latter is to identify hybrids and test the backcross pathways that are most suitable for introgression of the alien germplasm into maize.

Hybrid maize—As a follow-up to diallel studies completed last year with both normal and QPM lowland tropical and subtropical germplasm (see *1986 Research Highlights*), crosses were made among highland materials in 1987 and will be evaluated at several locations in 1988 to determine heterotic patterns among them. Studies like those are generating valuable information about the germplasm we already have, indicating how it can best be exploited by national hybrid programs. Other projects are intended to improve the usefulness of our germplasm and to create some new products that can be employed in hybrid development.

One effort that belongs in the former category involves the improvement of various pools and populations for tolerance to inbreeding, a trait in which tropical and subtropical materials are generally deficient. Very few survive the advanced stages of inbreeding, a fact that often imposes a fairly serious handicap on breeders, since they are then limited to using only early generation lines to form conventional hybrids. The improvement program now underway should substantially increase the probability that national program breeders will be able to extract superior inbred lines from the pools and populations. In another project we are trying to open the way for greater exploitation of two tropical populations

Harvest of a maize yield trial at Poza Rica, Mexico.

Countries of origin of maize in-service trainees, 1987

	Improvement	Production
Africa		
Benin	1	-
Burkina Faso	1	-
Egypt	1	1
Ethiopia	1	1
Ghana	1	2
Kenya	1	2
Mauritius	1	-
Morocco	1	-
Rwanda	1	-
Somalia	-	1
Tanzania	-	1
Total	**9**	**8**
Asia		
Bhutan	1	-
Burma	-	1
China	2	1
India	-	1
Malaysia	-	1
Nepal	1	-
Pakistan	1	-
The Philippines	-	1
Syria	-	2
Thailand	1	1
Turkey	1	1
Vietnam	2	-
Total	**9**	**9**
Europe		
Portugal	1	-
Latin America		
Bolivia	4	1
Colombia	2	1
Costa Rica	-	1
Cuba	1	-
The Dominican Republic	-	1
Ecuador	-	1
Guatemala	1	3
Honduras	1	-
Nicaragua	1	1
Panama	-	2
Paraguay	1	3
Peru	2	3
Venezuela	-	1
Total	**13**	**18**
Total trainees	**32**	**35**
Total countries	**25**	**25**

(Tuxpeño-1 and ETO Blanco) that are already well-known heterotic partners. In 1987 steps were taken to prepare them for interpopulation improvement, which will increase their combining ability.

Among the new products being identified or developed are heterotic groups, inbred and noninbred progenitors, tester lines, and conventional and nonconventional hybrids. As part of our effort to develop heterotic groups, we identified a number of lines in 1987 with good agronomic quality and will make and evaluate crosses next year to separate the former into combining ability groups.

Development of inbred lines for conventional hybrid formation and noninbred progenitors for nonconventional hybrids was continued in several pools and populations. So far, we have identified about 200 early generation tropical lines and 100 subtropicals that show good per se performance and agronomic traits. Seed of those lines is being multiplied and will probably be made available to national programs next year. Numerous other lines were placed in topcross trials and will be evaluated for combining ability, work that depends very much on the availability of suitable tester parents, as do many of the hybrid program's other activities. Based on the results of trials planted last year, various tropical and subtropical lines were identified and will be used as reference points by which new lines can be characterized for division into heterotic groups.

Important steps were taken in 1987 toward the development of conventional and nonconventional hybrids. Based on single-cross data gathered last year, a number of good three-way and double crosses were predicted and formed, and trials of predicted three-way and double crosses of tropical and subtropical germplasm were conducted in Mexico and in Central and South America. Among the nonconventional types, a number of topcross, intersynthetic, and double topcross hybrids were formed and are being evaluated in Mexico and at a few South American locations.

Direct Support to National Research Programs

All of the germplasm development work described in preceding sections is undertaken to support national maize programs, which are by far the main recipients of CIMMYT maize germplasm products. That work is complemented by two other sets of activities—training at Center headquarters and regional and bilateral programs abroad—that involve more direct contact with our clients. The primary contributions of those activities are 1) to provide staff in Mexico with a clearer picture of the germplasm needs of national programs and of the circumstances under which the germplasm is used and 2) to help strengthen the research capacities of national programs. The fact that about half of our staff time is committed to those activities underscores our conviction that without direct support to national programs our breeding efforts would lack direction and the seed we distribute would fall on much less fertile ground.

Training—The demand for in-service training in maize improvement and production continues to be quite high, exceeding the numbers of participants given in the accompanying table by about 60 percent. Various course modifications mentioned in last year's annual report (mainly a change in scheduling and a switch to offering the courses in only one language during a given cycle) were implemented during 1987. Those changes may have seemed cosmetic but in fact made a significant difference in the quality of training, permitting a large savings in time that trainees and instructors could devote to additional class, field, and laboratory work. Some new activities for which trainees had more time were autotutorials, short courses on the use of portable computers for data analysis, instruction on research reporting, and case studies of on-farm research projects.

In 1987, 55 visiting scientists spent from two weeks to several months at CIMMYT headquarters, consulting with maize staff and becoming familiar with the breeding and training programs. That number included seven staff of national programs who visited the Center for a month or more as part of a special visiting scientist fellowship program begun in 1986 with funding from various international chemical and seed companies. Most of the participants in 1987 came from Africa and are by and large senior staff in their institutions (several, for example, are university professors and one the national maize research coordinator of his country). In connection with that same program, one scientist from Guatemala began his master's degree studies with support from the government of Japan.

The number of pre- and postdoctoral fellows in the Program rose to 11 in 1987. Although such fellowships are classified as training, it is clear that what participants gain in experience from CIMMYT they more than repay through their contributions to the breeding and other programs. Work reported here on the epidemiology of tar spot, for example, was done by a predoctoral fellow and the evaluation of Tuxpeño Sequía by a postdoctoral fellow.

Regional programs—The Central American and Caribbean regional program planned a reorientation of its support to crop management this year, with the intention of narrowing the focus of this work and developing a more systematic means of assigning priorities to agronomic problems. Among the problems that will receive particular attention are soil erosion and management of volcanic ash soils.

The division of our eastern and southern Africa regional program into two was completed this year, and staff taking up new positions at Nairobi, Kenya, and Harare, Zimbabwe, were busy establishing their regional operations.

Since one of the maize specialists based in Nairobi is new to the regional program, he spent much of the year establishing contacts with national maize researchers and becoming familiar with their programs. His experience illustrates particularly well how regional staff go about identifying germplasm needs. At Kenya's Ol Joro-Orok station, for example, which is located at 2400 masl, he explored the possibility of testing some of our highland maize program's new populations and experimental varieties and gleaned useful information on the adaptation and performance of highland materials evaluated there previously. At the Bako research center in Ethiopia, he discussed with breeders the germplasm requirements of their hybrid development program. Afterwards, he arranged for inbred lines to be sent by our own hybrid program and expects that among those materials a good combiner will turn up that is compatible as a pollinator with an excellent female line already available in the Ethiopian program.

Participants in maize in-service courses at CIMMYT headquarters gain practical field experience in breeding or crop management research.

The other main task of regional staff, which is to strengthen research capacities in national programs, is accomplished in a variety of ways according to the extremely diverse circumstances of the national programs. Staff in eastern Africa, for example, consulted with maize researchers in Uganda to provide assistance in replenishing their program's stock of breeding materials, which was lost during a long period of civil strife. Staff based in Thailand helped establish an on-farm research (OFR) program in an area of the Philippines and participated in planning of OFR for central Thailand. In-country training in OFR was offered in Paraguay and Colombia by the Andean regional program. Our regional specialist based in Turkey organized a regional course on the use of personal computers for data analysis (a joint project with the Egyptian national program), assisted with a maize seminar for 19 researchers from various experiment stations in Morocco, and participated in a maize symposium in Turkey, which was held in connection with a reorganization of the country's maize research.

An important benefit of many regional activities is to encourage cooperation among national programs. That was the case with two traveling seminars in Bolivia and Peru, in which researchers from those and other countries in the region participated, along with CIMMYT staff and A.R. Hallauer, a US maize scientist of international stature. Another highly useful event in the Andean region was a workshop in Ecuador on abiotic stresses.

As part of an effort to overcome one of the principal abiotic stresses in the region, our staff based in Colombia are developing germplasm with tolerance to acid soils. In 1987 they channeled a large part of their breeding resources into international evaluations of some 1200 lines from 50 sources to identify parents for the formation of four populations. In addition, progeny trials were conducted with another population that is already being improved for tolerance to acid soils.

For additional details on some regional activities and on our bilateral projects, see the reports on extra-core grants (pages 54-55 and 58-59).

Maize Program

The Program's multidisciplinary team consists of 19 international staff at CIMMYT headquarters and 22 posted at locations outside Mexico. Most staff at headquarters are engaged in germplasm development or related activities. Those working in other countries provide direct support to national research programs, and some conduct breeding projects as well.

Development and Distribution of Germplasm

Gene pool development and improvement
General-purpose pools: Broad-based materials, each representing one of the various maize types grown in the developing countries and possessing reasonably good agronomic quality and field tolerance to a number of stresses.

Special-purpose pools: Agronomically acceptable source materials into which genes are incorporated for tolerances to one or a few biotic or abiotic stresses.

Population improvement
Improve advanced populations and develop experimental varieties from them.

International testing
Distribute families and experimental varieties drawn from advanced populations, supply test results to CIMMYT breeders and clients in national programs, and use this information to identify superior families and varieties.

IPTTs: International Progeny Testing Trials
EVTs: Experimental Variety Trials
ELVTs: Elite Variety Trials

Special classes of germplasm
Highland maize: Develop germplasm for highland environments and consult with breeders serving highland areas in national programs.

Direct Support to National Research Programs

Regional programs
Identify the needs of national programs and strengthen their maize breeding, agronomy, and other research capacities through consultation, in-country training, and regional workshops and conduct germplasm development activities that are not practicable at Center headquarters.

- **Andean zone:** Develop germplasm tolerant to aluminum toxicity.
- **Asia:** Develop downy mildew-resistant germplasm.
- **Eastern Africa**
- **Central America and the Caribbean**—Develop corn stunt-resistant germplasm.
- **Middle East/North Africa**
- **Southern Africa**

Bilateral projects
Strengthen maize breeding, agronomy, and other research capacities in selected national programs through close, continuous contact over an extended period.

Training
Offer in-service courses (on breeding, production, and protein-quality analysis), visiting scientist fellowships, and post- and predoctoral fellowships at Center headquarters.

***Quality protein maize (QPM)*:** Develop germplasm that possesses improved protein quality and yields comparably with normal maize.

CIMMYT/IITA breeding program
Develop streak-resistant germplasm at the International Institute of Tropical Agriculture (IITA) in Nigeria and midaltitude maize at Harare, Zimbabwe.

Support of Germplasm Development

Six support units contribute to the various breeding programs by providing germplasm, techniques, and information that can be employed in germplasm development.

Pathology
Develop sources of disease resistance, improve resistance in elite materials, and conduct basic pathology studies.

Entomology
Develop source germplasm possessing resistance to insects and acceptable agronomic type and rear sufficient numbers of maize insects for resistance screening.

Physiology
Develop source and elite materials showing tolerance to abiotic stresses such as drought and devise efficient techniques for selecting for tolerance.

Germplasm bank
Conserve and distribute seed of bank accessions, manage a database containing information about these materials, and generate new information by evaluating the germplasm.

Wide crosses
Transfer desired traits into maize through crossing with its wild relatives and investigate the use of techniques developed through biotechnology research in practical plant breeding programs.

Hybrid program
Generate germplasm and information that enables national program breeders to develop conventional and nonconventional hybrids more efficiently.

Wheat Research

1987 began with a successful international conference in January entitled Wheat Production Constraints in Tropical Environments in Chiang Mai, Thailand. It ended with a signed agreement establishing a breeding partnership with China to improve wheat resistance to scab.

In between those events were internal reviews and consultancies that began our Program's role in the process of developing CIMMYT's strategic plan, significant changes in our bilateral and regional programs, and a heavy schedule of international and regional conferences and workshops. What follows are some of the details about those events, which shaped the beginning of a pivotal period for our Program.

Internal Reviews and Outside Consultancies

In April at Ciudad Obregón, members of the CIMMYT Board of Trustees Program Committee reviewed the bread wheat, durum wheat, triticale, and barley programs as well as the support and outreach programs (see box on program organization and activities, pages 42-43). That exercise was helpful in our preparation for the External Program Review scheduled for March 1988.

In June and July, we invited two international panels of eminent scientists to El Batán; one assisted us in reviewing Program strategies related to germplasm improvement, and the other examined current worldwide breeding approaches, with specific emphasis on CIMMYT's, for achieving resistance to the rusts of wheat. The internal review and the two consultancies were the first crucial steps aimed at developing the Center's overall strategic plan as well as future priorities in the Wheat Program.

Germplasm improvement—The panel reviewing the Program's germplasm improvement strategies agreed that our traditional program of breeding for broad adaptation should be maintained because it has been successful in the past and because it is needed as a source of parents and a yardstick against which to measure other projects. They also pointed out that the biological principle underlying the mega-environments concept is sound and supported the idea of more focused breeding projects as a way of improving overall efficiency and at least enhancing progress in target areas. There was a consensus that the concept of mega-environments does not contradict that of shuttle breeding, provided that the selection sites sampled are relevant to the particular mega-environment.

The panel felt the Program has made a good and systematic effort to widen the genetic base of triticale by developing a wide range of new primary crosses. They also lauded the spring x winter crosses and wide crosses programs, which have both made useful contributions to the germplasm base of wheat breeding. Concern was expressed, however, that new

During the internal program review at Ciudad Obregón, Mexico, Pedro Brajcich, head of the durum wheat program (left), describes his program to members of the Program Committee of CIMMYT's Board of Trustees from left: James McWilliam, Peter Day, and Stachys Muturi.

germplasm being introduced into our breeding programs each year might be eliminated by too stringent selection in early generations. All agreed that the germplasm base merits high priority and a systematic approach in handling it.

This panel also made comments about the Program's germplasm distribution to national collaborators, the type of research we do (practical versus strategic), the integration of agronomy and breeding efforts, international collaboration, data management, and our involvement in biotechnology—all of which will be useful as we reevaluate Program priorities in the context of developing CIMMYT's strategic plan.

Strategies for rust resistance—The second panel of internationally recognized specialists was charged with the task of reviewing the current situation and defining a broad breeding strategy that could be implemented in the future to incorporate necessary resistance to control leaf, stem, and stripe rusts in wheat. A 10-chapter publication that sheds new light on wheat rust resistance breeding resulted from the meeting and will be available in April 1988.

The general consensus of the panel was that the Program has so far been intensely practical and that overwhelmingly the biggest output has been a stream of excellent new wheat varieties. They felt that, with improved yield potential secured, the time is ripe for a shift towards enhanced understanding of wheat breeding strategies, including a substantial element relating to stable disease resistance. The panel added that a shift from practical breeding towards strategic research is not at all remote from the Program's current preoccupations with the importance of stability of resistance, the need for combining durable resistance and partial resistance with major genes, and the exploitation and study of interaction or mixture resistance.

The Breeding Programs

In 1987 progress continued in the crop improvement programs. The bread wheat program crystalized its approaches to breeding for rust resistance during the milestone rust conference discussed above. As outlined at the conference and explained in the forthcoming proceedings, the bread wheat program feels the principal thrust must be durable resistance expressed as partial resistance in conjunction with major genes that confer additional security.

The durum wheat program intensified its shuttle breeding efforts between Mexico and Ethiopia, Kenya, and Turkey to enhance resistance to stem and leaf rusts and other diseases in the crop. And renewed effort was made to broaden the variability of traits influencing semolina quality.

The triticale program continued its thrusts to widen the crop's variability. Successes along those lines included the apparent transfer of scab tolerance from Chinese wheats and added variability for earliness from wheats and rye. And in 1987, for the first time, those crosses produced test weights of 80 kg/hectoliter.

The Turkey/CIMMYT Collaborative winter wheat program began its third year of efforts to develop broadly adapted, high-yielding winter wheat germplasm for the extensive winter wheat and facultative wheat areas of Turkey and the world. See more details about winter wheat work in the next section.

Breeding Partnerships

The Wheat Program has always valued the close working relationships that have existed through the years with the multitude of national programs around the world. We have been very aware of and responsive to national program needs, sensitivities, requests, and levels of competency. Over time, a number of national programs have progressed from simply being recipients of germplasm to cooperating in successful shuttle breeding activities. As those programs advance even further in expertise, capability, and interest in a particular constraint to wheat production, it seems logical that the next step in our evolutionary relationship with them should be to involve their scientists in breeding partnerships.

Those arrangements, the terms of which were defined in 1987, will center on the successful shuttle breeding system, in which respective generations are grown alternately in Mexico and the partner country. However, the execution of the project and the selection process will involve, not only CIMMYT staff, but also the national program staff at all stages of generation development. Wheat Program and national scientists will work together in making selections in Mexico and the cooperating country, deciding which materials will be advanced and determining the direction of the project.

The next step in our evolutionary relationships with national wheat programs that are quite advanced in their work on a particular constraint will be to form breeding partnerships with them.

Each international nursery containing materials developed in a partnership arrangement will be distributed in the name of the national program and CIMMYT. For example, in the partnership agreement signed with China in 1987, a China-CIMMYT International Scab Screening Nursery is envisioned. In our partnership with Turkey, the screening nursery distributed from Turkey will soon be called the Turkey-CIMMYT International Winter Wheat Screening Nursery. In 1987 discussions began with Brazilian research institutions to develop a partnership that may eventually lead to a Brazil-CIMMYT International Aluminum Toxicity Tolerance Screening Nursery. In addition to that with Brazil, other proposed partnerships for the immediate future include ones with Argentina, Mexico, and India.

Turkey—The Turkey/CIMMYT Collaborative Program for winter wheat is a breeding partnership that marks an important shift for our Program in that a major part of a breeding program is located outside of Mexico. Work continued toward several of the program's objectives during the 1987 cycle.

Improvement of spring wheats from winter x spring crosses is a well-established fact, and since there is no scientific reason why winter wheats should not benefit to the same extent, this effort will receive major emphasis. As part of that activity, an elite group of winter wheat cultivars and advanced lines, both bread and durum wheats, were sent from Turkey to Mexico to be crossed with the best spring wheats. The F1s were returned to Turkey and during the 1987-88 cycle will be topcrossed to winter wheats.

Seed multiplication for the international winter wheat nurseries was established during 1987, so that sufficient quantities of seed will be available to both the international and Turkish national programs. The Third International Winter Wheat Screening Nursery, consisting of 87 entries, was assembled and shipped to 65 winter wheat locations around the world. Also in 1987 a program was initiated to screen the winter wheats for resistance to common bunt (*Tilletia foetida*), a serious problem in many winter wheat areas.

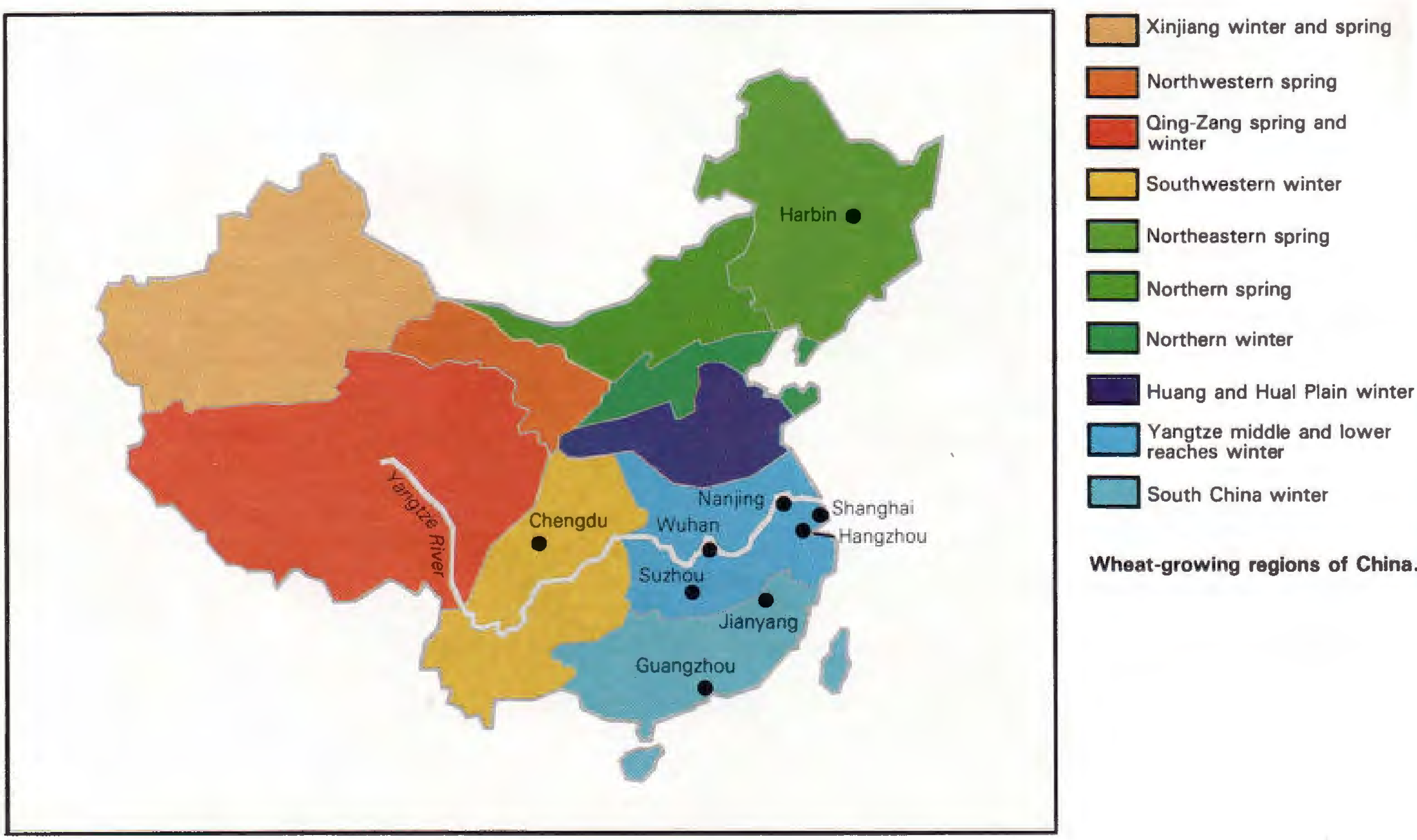
Gene Saari (left), Hans-Joachim Braun, and Bent Skovmand, breeder/pathologists assigned to the Turkey/CIMMYT Collaborative Winter Wheat Program, inspect the winter wheat drought nursery at Hamidiye, Turkey.

China—Over the last four years, we have had a shuttle breeding program with various Chinese institutes in the country's southern areas where spring wheat is planted in the fall and grows during the winter season, principally the Yangtze River Basin, to develop better materials for scab resistance. Under the terms of the new breeding partnership, we will try to incorporate resistance into Mexican-type germplasm by using Mexican/Chinese//Mexican crosses. The Chinese will be incorporating some of the traits from the Mexican wheats into their own germplasm base by making Chinese/Mexican//Chinese crosses. Over time we hope to see which of those schemes works best.

In China most of that work will be done in cooperation with wheat research institutes located in the middle and lower reaches of the Yangtze River Valley; Nanjing and Chengdu will be two primary sites (see map). Chengdu needs less scab resistance than Nanjing but requires very strong straw and a sturdy root system, particularly strong lateral roots to prevent lodging during irrigation. Current CIMMYT wheats without strong lateral roots tend to lodge severely. Other sites along the Yangtze and in South China will include Wuhan, Jianyang, Shanghai, Guangzhou, Suzhou, and Hangzhou. The Chinese have also asked to set up a shuttle with the spring wheat program in the northeast province of Heilongjiang, near Harbin.

Brazil—Our scientists have had a long history of successful cooperation with a number of Brazilian research institutions. The 15-year shuttle breeding effort with Brazil has resulted in a number of higher yielding, aluminum-tolerant wheat varieties (see *CIMMYT Research Highlights 1986*, pages 37-47, for a complete report on this venture). The Brazilian national program (see box, pages 34-35) provides an excellent example of growth in a developing country's competence to the point where it has the expertise to make a strong contribution to the development of international wheat germplasm.

Continued on page 36



Wheat-growing regions of China.

Wheat Breeding in Brazil

Starting with this *1987 Annual Report*, we will profile, each year, one of our national program clients. The program featured usually will coincide with the most recent issue in our CIMMYT Today series that highlights the detailed progress of that national program.

It is no surprise that we commence this series with Brazil—a long-time CIMMYT collaborator. Even though Brazil is not known for its wheat production—coffee, sugarcane, soybeans, and orange juice more often come to mind—the Brazilian wheat breeding program has been described as one of the outstanding programs in the world in terms of its breeding network, screening of material, and developing varieties.

Wheat production in Brazil.

Brazil got to that point through a strong tradition in wheat breeding efforts dating back to the early 1900s. Much of the credit for today's successes must be given to pioneer Brazilian breeders such as Benedito Paiva, Iwar Beckman, and Carlos Gayer, and breeders who came after them such as Orlando Gomes Nobre, Mário Bastos Lagos, Ady Raul da Silva, and Milton Alcover. Many of those breeders pioneered the development of wheat varieties with tolerance to aluminum toxicity, a major production constraint throughout the region and the reason CIMMYT has been involved in a successful shuttle breeding program with a number of Brazilian institutions in the 1970s and 1980s and why now a Brazil/CIMMYT breeding partnership is in the works.

However, the country's new generation of breeders, pathologists, and agronomists, such as Carlos Riede, Ottoni de Sousa Rosa, Francisco Franco, and Nelson Neto also cite training and scientific visits at CIMMYT as another major reason for Brazil's advances in wheat production, particularly over the last 20 years. Since 1969, 23 Brazilian researchers have participated in CIMMYT's wheat improvement, production, cereal technology, and experiment station courses. As John Gibler, former associate director of the CIMMYT Wheat Program and technical advisor to Brazilian research institutions throughout the 1970s, points out: "Training has been and is the key. If a breeding program has only germplasm without trained people, it will stand still."

Throughout the last 15 years, CIMMYT has collaborated primarily with six Brazilian institutions to varying degrees (see map). Organizations with which it has strong shuttle breeding programs to develop high-yielding, aluminum-tolerant wheat varieties include the cooperative-supported Federation of Wheat and Soybean Cooperatives (FECOTRIGO) and the Organization of Cooperatives of the State of Paraná (OCEPAR) and the federally supported Brazilian Agricultural Research Enterprise (EMBRAPA). CIMMYT also works with state-supported institutions, such as the Agronomic Institute of Paraná (IAPAR), the Campinas (São Paulo) Agronomic Institution (IAC), and the Minas Gerais Enterprise of Plant and Animal Research (EPAMIG).

Brazil produced more than 6.1 million tons of wheat in 1987 on some 3.4 million hectares, supplying around 87%—an all-time high—of the needs of its 138 million people. Wheat is grown primarily in five southern states (see map). There is potential to expand wheat production to other regions of the country, primarily in the Cerrados (see map), which has some 200 million hectares of savanna-like scrub vegetation, half of which is considered to be arable and could someday be planted to various crops, including wheat.

Advances in production technology, combined with the availability of vast tracts of unexploited arable land suggest a huge potential for expanding the country's wheat production. However, whether or not Brazil achieves long-term self-sufficiency in wheat will most likely depend on the policy environment, which determines the economic incentives facing producers and consumers.

For a detailed report on this fascinating country and its wheat research progress, see CIMMYT Today No. 18, *Wheat Production in South America's Colossus: Progress in Brazil's National Agricultural Research Program*, scheduled for publication in mid-1988.

Ricardo Matzenbacher (left), and Nelson Neto, former CIMMYT trainees and breeder and pathologist, respectively, for the Experimentation and Research Center (CEP) of FECOTRIGO, inspect CEP demonstration plots at Cruz Alta, Rio Grande do Sul, Brazil.

The proposed breeding partnership with Brazil would be to develop high-yielding wheats with better tolerance to acid soils including aluminum toxicity, but the effort also would include work on resistance to major diseases that are rampant in that region, including both septorias, helminthosporium, scab, leaf rust, and stem rust.

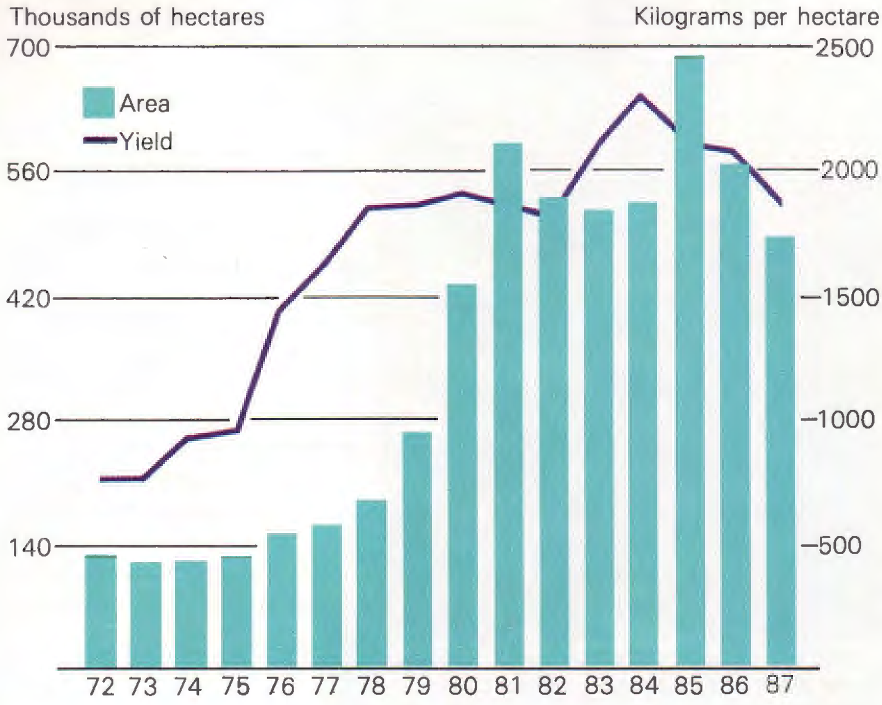
Developments in Outreach

Bilateral projects in Pakistan, Peru, and Turkey came to logical conclusions in 1987; however, the national programs of these countries will continue to maintain close contacts with CIMMYT through our regional programs in South Asia and the Andes and the Turkey/CIMMYT Collaborative Program for winter wheat based in Turkey. For details see the Extra-Core Grants section.

Pakistan—Special note is warranted with the closing of the USAID-funded Pakistan Wheat Program, which was initiated in October 1984. Our involvement in Pakistan started in the early 1960s and revolved mainly around introduction of new improved, fertilizer-responsive germplasm and use of nitrogen fertilizer for increasing wheat production. Since those days we have actively helped develop a good wheat breeding capacity in Pakistan through training and exchange of improved germplasm. Most of the country's wheat breeders have been trained at CIMMYT or have visited at some time in their careers.

That type of support was continued through September 1987. About 160 nurseries evenly split between CIMMYT and the International Center for Agricultural Research in the Dry Areas (ICARDA) containing valuable germplasm were imported and distributed to the various provincial and national wheat programs each year of the project. A publication, entitled *Research and Development in Pakistan: A National Perspective*, was commissioned to chronicle the last 25 years of wheat and maize research in Pakistan by bringing together the work and reports of the many individuals who have made notable achievements.

A lot of progress has been made in wheat research since CIMMYT collaboration with Pakistan began; production has increased from 4 million tons in 1965 to 14 million in 1986. Today the majority of Pakistani farmers grow improved varieties with some level of fertilizer use. However, there is still a yield gap that farmers could bridge by using better crop management and adopting technology to raise the yields of high-yielding varieties. Crop management research in Pakistan must be reorganized to promote practical on-farm, multidisciplinary, problem-oriented research for specified cropping zones. Better seed production and distribution technology needs to be adopted to enhance capacity to replace old susceptible varieties.



Wheat production in Bangladesh.

Bangladesh—Phase I of the Wheat Program's one remaining, and very successful, bilateral project with Bangladesh—supported by the Canadian International Development Agency (CIDA)—comes to a conclusion in June 1988. Phase II of that project is proposed to commence on July 1. Fifteen years ago, many people in Bangladesh said that wheat could not grow there. However, the expansion of wheat cultivation has been unrivaled in relative terms. The crop's area increased from 125,000 ha of low-yielding, unimproved varieties in 1974 to almost 700,000 ha of well adapted modern varieties by 1985—a growth rate of almost 40% per annum (see figure). That increase (accomplished through the dedicated efforts of a catalytic team of Bangladeshi wheat scientists) reflects the fact that wheat products have been accepted by the general population and are now eaten widely on a regular basis.

The relationship between CIMMYT and the Bangladesh National Program has been close since 1968 when the first Bangladeshi trainee, Dr. Sufi Ahmed, now director of the national program, arrived in Mexico for instruction in wheat breeding.

In the short span of 10 years, Bangladesh has moved from the ranks of the nontraditional wheat-growing countries into what can be called the traditional wheat-growing countries. This makes us all the more optimistic that similar changes can be accomplished in other countries, particularly the northern areas of Thailand.

The proposed second phase will specifically address the crucial agronomic issues of apparent wheat production declines observed in 1986 and 1987. Increased cropping intensity concomitant with the depletion of organic matter reserves due to alternative uses of stubble (fuel, feed, etc.) has led to declining soil fertility and perhaps proliferation of soilborne pathogens.

Ethiopia—In 1987 Ethiopia declared wheat, particularly bread wheat, a national priority food crop, and the government increased scientific attention, personnel, and funds devoted to the crop. That effort coincides with the relocation from Nairobi to Addis Ababa of the CIDA-funded agronomist for the East Africa Cereals Project and the core-funded pathologist/breeder. The move to Ethiopia is designed to foster a closer working relationship with the country's Institute of Agricultural Research (IAR), particularly to help strengthen its agronomy and pathology efforts.

IAR has four research centers situated in the major small-grain agroecological zones, plus several subcenters in some minor zones. The project agronomist has assisted staff at each station in conducting multidisciplinary surveys to identify the major farm-level constraints. As a result, priority research themes are being developed into specific trials, which are providing the necessary focus for a well-integrated on-farm/on-station agronomic research program.

The CIMMYT pathologist/breeder in Addis Ababa is assisting the national program in prioritizing diseases as to prevalence and crop losses, conducting host and pathogen surveys, developing a multilocational germplasm screening network, and identifying effective selection methodologies. Our bread wheat and durum wheat programs at headquarters are involved in shuttle breeding with Ethiopia, which is a "hot spot" for a number of diseases. In addition, a 10-year plan to breed for better disease resistance has been formulated by cooperative efforts of our pathologist/breeder and IAR researchers. For more information on the East Africa Cereals Project, see the Extra-Core Grants section.

Marginal Environments

Our priority for developing wheats for marginal environments got a boost in July from the United Nations Development Programme (UNDP) with its agreement to fund a three-year restricted-core project, Development of Wheat Varieties for Marginal Areas. That venture is a continuation of the UNDP-funded project, Research on Tropical Wheat Improvement, which terminated in June. Outreach staff assigned to that project will continue to be headquartered in Bangkok, Thailand, and Asunción, Paraguay, at least through June 1990. Also in 1987, a pathologist was assigned to the Asunción office.

Wheat products are now regularly consumed in Bangladesh, as can be seen by the output of this cookie factory in Dhaka.

Crop management research is considered particularly appropriate for marginal environments, where many of the benefits of improved germplasm currently remain unexploited.

The overall objective of the project is to assist the countries of the tropical belt in their search for ways to improve or introduce domestic wheat production. Germplasm development for heat and drought tolerance, disease resistance, early maturity, day-length insensitivity, and tolerances to acidity, alkalinity, and aluminum toxicity is being done through local breeding activities in Mexico, South and Southeast Asia, and the Southern Cone of South America.

In 1987, CIMMYT's international testing program distributed more than 100 tropical wheat nurseries (Helminthosporium and Warmer Areas Screening Nurseries) to 67 countries throughout the world. The specialized Hot Climate Wheat Screening Nursery, consisting mostly of non-CIMMYT materials and up to now distributed within the South and Southeast Asian regions, was made available on a global scale. In Thailand, for the first time since the Thai wheat breeding program began in the early 1970s, some locally made crosses were included among 39 outstanding lines identified in multilocational trials. In Paraguay 16 lines exhibiting a high level of drought tolerance were selected and are being prepared for testing during 1988 in Paraguay, Bolivia, and Argentina.

CIMMYT hosted 10 in-service trainees and seven visiting scientists from Indonesia, the Philippines, China, Burma, India, Thailand, Malawi, Nigeria, and Sudan. A major international conference on constraints to wheat production in the tropics was held in Chaing Mai, Thailand (see Conferences and Workshops section for details).

In the next section, our wheat agronomist in Southeast Asia has some pertinent observations on wheat crop management in the tropics based on four years of experience in the region.

Crop Management Research

In 1987 we intensified our commitment to crop management research (CMR). For example, agronomists and breeders in the South and Southeast Asia regions began important sustainability work involving the rice-wheat rotation. The rice-wheat cropping pattern represents approximately 17.7 million hectares or 28% of the cultivated wheat area of South and Southeast Asia. What undoubtedly will become a major point in CIMMYT's ongoing strategic planning process is that CMR is considered particularly appropriate for such marginal environments, where many of the benefits of improved germplasm currently remain unexploited. After four cropping cycles (1983-87) in the Southeast Asia region, our agronomist there has summarized some of his observations in the lower altitudes (less than 500 masl), where wheat is grown following rice with either full or partial irrigation.

Constraints to wheat growth—Elevated temperatures speed up plant development phases, typically resulting in fewer plant parts (productive tillers) or smaller individual plant parts (spikes and grains). At the same time, high relative humidities promote diseases for which little or no resistance is available in adapted genotypes. In addition, wheat yields in the tropics are inherently less stable due to variability in radiation, temperature, and rainfall over the shortened plant development stages.

While it is said that elevated temperatures are a major constraint to high wheat yields in the tropics, this is not exactly correct. In a paper given at a meeting on wheat production constraints in tropical environments held in January at Chiang Mai, Thailand, H.M. Rawson of Australia's Commonwealth Scientific and Industrial Research Organization, proposed that the effect of temperature, in reducing plant development phases, creates increased demand on the *rate* of supply of the main growth resources—radiation, nutrients, and water. In fact, he has obtained 10 t/ha from the variety Tobari grown at night/day temperatures of 16°/34°C with nonlimiting radiation, nutrients, and water under controlled conditions.

Prime management concerns—Under average wheat-growing conditions in Southeast Asia, the number of spikes produced per square meter is rarely more than 250-300, which keeps yields in the 1.5- to 2.0-t/ha range. Genotypes tested so far have shown little variability for that factor. However, with good fertility and adequate moisture, tiller populations of 450 per square meter, and yields between 4 to 5 t/ha have been attained. This indicates that prime concerns of wheat crop management in the tropics are to encourage practices that minimize the effect of temperature and maximize the availability of nutrients and moisture.

Seeding date—In most localities of Southeast Asia, the usual one-month seeding period results in an unexplained yield plateau. This plateau may result from the radiation received per unit temperature being less variable at low latitudes or may be due to current yield levels being well below the genetic potentials. There are limits to extending the seeding period: seeding too early results in excessive temperatures during juvenile plant development, while late seeding results in rapidly increasing temperatures during grain filling. Late seeding is the greater problem in Asia, due either to late rice harvest or difficulties in converting rice paddies into seedbeds suitable for an upland crop. Minimum or zero tillage may offer a solution to that problem, although disease and insect problems will require monitoring.

Seeding depth—Generally, a seeding depth of about 5 cm has produced plants with superior tillering, larger leaves, and more grains per spike than shallower depths. The practice of hill farmers in northern Thailand has been relatively successful. A hole is made, seeds are inserted, and a small amount of soil is placed over the seeds; the deep placement of the seeds provides a cooler environment for enhanced root growth while the shallow seed coverage allows for rapid emergence and earlier start of photosynthesis. Up to six tillers per plant have been recorded utilizing this method in environments where other seeding methods rarely have resulted in more than two ear-bearing tillers per plant.

Fertilizer application—Because of the generally low fertility of lowland rice soils in Southeast Asia, wheat cultivation in rotation with rice cannot be considered unless fertilizer is applied. However, nitrogen efficiency is low, typically generating a response of about 8 kg of grain per kilogram of nitrogen, which in some countries barely covers costs. There is no evidence that splitting nitrogen applications or that different nitrogen sources affect the efficiency. Response to phosphorus application has been negligible, even though most soils in the region are phosphorus-poor. Sulfur deficiency is becoming widely recognized and multiple micronutrient deficiencies are now being diagnosed. Those problems obviously are part of the reason for the poor nitrogen responses.

It has become clear that fertilizer management can affect the reaction of wheat to many tropical diseases. The relatively weak pathogens of those diseases perform best on crops grown under less than optimum conditions, be they low fertility, waterlogging, drought, or heavily compacted soils. The control of those diseases should be accomplished through an integration of proper agronomic management, genetic resistance, and strategic application of fungicides.

Future challenges—In addition to increased disease resistance, breeding priorities in the marginal environments should be aimed at increasing productive tillers per plant under hot conditions and developing plants with rapid early root growth. However, even with those gains in germplasm, the gains from management research should be substantially greater. The challenge appears to be finding out why it is not possible in the majority of Southeast Asian environments to obtain more than 250-300 spikes per square meter, when isolated pockets within the same climatic conditions can support 450 spikes. The reasons may be tied to a complex relationship of soil physical problems, soil pathogen and microorganism attacks, and nutritional factors. The practical solution to that dilemma would have wide impact, not merely in the tropics, but over millions of hectares in the subtropical wheat-growing regions.

Training

Wheat improvement and production in-service courses provided practical training for 45 wheat researchers from 25 countries in 1987 (see table, page 40).

Improvement—The improvement course has three main educational objectives: 1) providing trainees with research skills and knowledge needed to run a wheat improvement program,

Ray Villareal, Wheat Program training officer (left), explains the day's field work at the Toluca station to 1987 improvement trainees Freddy Fernandez (Bolivia), Sevket Metin Kara (Turkey), U Kyin Po (Burma), and Edgar Guzman (Bolivia).

Countries of origin of wheat in-service trainees, 1987

	Improvement	Production
Africa		
Ethiopia	-	2
Kenya	1	-
Malawi	-	1
Morocco	-	1
Nigeria	-	3
Somalia	-	1
Sudan	-	1
Tunisia	2	-
Total	**3**	**9**
Asia		
Afghanistan	1	-
Burma	2	-
China	2	-
Indonesia	1	-
Iraq	-	1
Nepal	2	-
The Philippines	1	1
Saudi Arabia	1	1
Thailand	1	1
Turkey	4	-
Total	**15**	**4**
Latin America		
Bolivia	2	-
Brazil	-	1
Chile	1	1
Colombia	2	2
Mexico	2	-
Paraguay	-	2
Peru	-	1
Total	**7**	**7**
Total trainees	**25**	**20**
Total countries	**15**	**15**

2) developing trainees' ability to synthesize new forms of wheat technology, and 3) fostering specific types of attitudinal changes among trainees.

The 1987 course, which began at Ciudad Obregón on February 23 and ended at Toluca and El Batán on October 2, instituted some key new features for the 25 trainees. One was a field day at Toluca, which the trainees were solely responsible for organizing and conducting. Another was the implementation of a rust surveillance exercise in farmers' fields in Ciudad Obregón, which gave the trainees experience in conducting an actual disease survey and analyzing the collected data.

Production—Twenty production trainees were exposed to both theoretical and practical principals that agronomists need to do their job. During the course, which ran from April 20 to November 25, trials were conducted in farmers' fields and on station. Each trainee was assigned primary responsibility for an on-farm trial, while on-station trials were run on a group basis. The trainees, with assistance from the training office and crop management staff, designed the trials, prepared treatments, laid out the plots, and did the planting. Maintenance, harvest, and analysis of the trials were also responsibilities of the trainees under supervision. In 1987, besides assessment throughout the course, trainees were given special evaluations of their practical skills over a two-day period and of their theoretical skills for one day.

Visiting scientists—CIMMYT has begun emphasizing longer and more substantial programs for certain of its visiting scientists through a fellowship program initiated in 1986. During those fellowships, funded by chemical and seed companies in the USA, West Germany, and Switzerland, more concrete results can be attained for the benefit of the scientists' home countries and CIMMYT. See the box on a visiting Indian scientist, sponsored by Pioneer Overseas Corporation, who provided a major payoff in 1987 at Ciudad Obregón with his work on Karnal bunt, a wheat disease of current major interest to both India and CIMMYT.

International Nurseries

In 1987 we sent collaborating scientists in 87 countries 2107 sets of bread wheat, durum wheat, and triticale nurseries plus 515 sets of special nurseries (see appendix, pages 79-80). In addition, in cooperation with ICARDA, we prepared and distributed 276 sets of barley nurseries for testing in 63 countries.

The information returned by cooperators helps us to better direct the breeding program and set priorities for more useful germplasm for various mega-environments. That approach, using the information derived from the international nurseries in our crossing program in Mexico, followed by the selection of superior advanced genotypes at testing sites in Mexico and other locations, known as multilocational testing, has proved to be an extremely effective breeding strategy for bread wheat, durum wheat, triticale, and barley.

Conferences and Workshops

Many of our staff members had heavy travel schedules in 1987. Much of the travel can be attributed to expanded shuttle breeding efforts in China, Brazil, Ethiopia, Kenya, Turkey, Morocco, and other countries. However, there was also a busy schedule of two major international and three regional conferences held in Thailand, Italy, Paraguay, Madagascar, and Uruguay. Details of those meetings follow.

Wheat Production Constraints in Tropical Environments—This international meeting, jointly sponsored by CIMMYT and UNDP, held in Chiang Mai, Thailand, January 19-23, was the second major conference addressing the problems associated with introducing wheat into the warmer environments of the world. Eighty-three wheat scientists from 27 countries in Asia, Africa, and North and South America participated. Twenty-five invited papers discussed the major constraints that confront wheat in the nontraditional areas. Breeding, pathology, and agronomy discussion groups identified future research objectives, established priorities, and identified areas for international cooperation. The conference proceedings will be available in June 1988.

Barley Yellow Dwarf Workshop—This international meeting, jointly funded by Italian institutions and CIMMYT, held in Udine, Italy, July 6-11, was the second major conference addressing the problems caused by Barley Yellow Dwarf (BYD), which is ubiquitous in the world's cereal crops. The conference was attended by 119 participants from 35 countries. The attendance of 43 participants was either completely or partially paid for with Italian funding. The workshop proceedings of more than 100 papers are scheduled for publication later in 1988.

Visiting Scientists Aid in Karnal Bunt Research

During the first half of 1987, Dr. H.S. Dhaliwal, senior scientist-cum-director of the Regional Research Station of Punjab Agricultural University, spent several months as a visiting scientist, sponsored by CIMMYT's new fellowship program. He was attached to the pathology program's Karnal bunt project.

Karnal bunt (KB) is a disease of wheat and triticale caused by the weakly pathogenic fungus, *Tilletia indica*. The disease was first reported from Karnal in northern India in 1930. Since then KB has assumed epidemic proportions in northern India and has spread to a number of other countries, including Pakistan and Mexico. There is an urgent need to develop KB-resistant wheat varieties to avoid deterioration of wheat product quality and the disease's spread to other parts of the world.

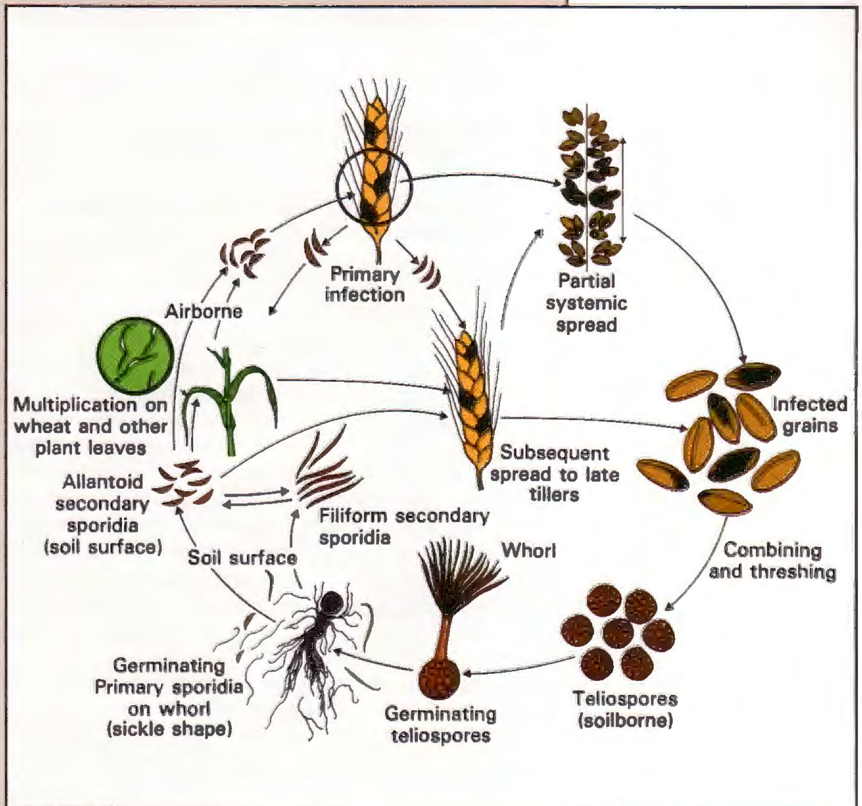
Dhaliwal, working with our pathologists and using the research facilities at Ciudad Obregón, discovered new information on the disease organism's complex life cycle and, with another Indian visiting scientist, worked on the development of approaches to screening for resistance components.

Updated life cycle—Until recently little was known of what occurred in nature during the period between the production of primary sporidia and the appearance of bunted kernels in the mature wheat spike. Laboratory work conducted by Dhaliwal and CIMMYT pathologists showed that allantoid secondary sporidia are likely the most common incitant of KB in nature and that the opening of glumes at anthesis for direct ovary infection is not necessary for the disease to occur.

The airborne allantoid secondary sporidia can germinate on the glume surface and become partially systemic in the rachis and rachilla. Dhaliwal claims that, under both natural and artificial inoculation, the disease spreads to adjacent florets and spikelets, infecting as many as 30 grains around the primary infection site. According to him, the highest damage to the grains occurs at the spikelet of primary infection, while systemic spread results in point infections or outbreak on the kernels. In the infected spikes, KB colonies are also established in the florets, especially between glume and lemma or lemma and the dorsal seed surface to produce more allantoid secondary sporidia, which become airborne and capable of infecting late wheat tillers (see figure). CIMMYT pathologists are continuing research to confirm these findings.

Breeding for resistance—For transferring KB-resistance to bread wheat, Dhaliwal and visiting scientist D.V. Singh, wheat pathologist for the Division of Mycology and Plant Pathology of the Indian Agricultural Research Institute, New Delhi, suggest a crossing program using durum wheat lines that have proven to be resistant to KB after boot inoculation. Yavaros 79, Ward, Mexicali 75, 68111, and Dack'S' appear to be promising durum wheat parents for transferring KB resistance to bread wheat.

For more detailed information on the Karnal bunt work at CIMMYT, see the pathology section of the *CIMMYT Biennial Report on Wheat Improvement, 1985-86*.



Dhaliwal's updated life cycle of *T. indica*.

Scab Workshop for the Southern Cone—This workshop, held in Encarnación, Paraguay, September 7-12, was organized by our Southern Cone staff with the help of the Paraguay national program. The meeting looked at current advances in combatting this serious wheat disease and planned future strategies. A major accomplishment was to get together the CIMMYT scab program, now based in Paraguay, with the regional collaborators to develop future integration and testing of selected germplasm at key locations in the region.

Regional Wheat Workshop for East, Central, and Southern Africa—This meeting, jointly sponsored by CIDA and CIMMYT and held in Antsirabe, Madagascar, October 5-10, was attended by 30 scientists representing the national wheat research programs of 11 countries in the region. This continued the tradition of biennial meetings for the region, which began in Zambia in 1981. Zaire and Somalia were represented for the first time. Papers dealt primarily with agronomy, breeding, and pathology problems unique to the region. Participants urged the decentralizing of germplasm screening in East Africa, which would give responsibility for hot-spot screening and germplasm distribution to several of the larger national programs. Publication of the workshop proceedings is scheduled for later in 1988.

Regional Conference on the Septoria Diseases of Wheat—This conference, financially supported by the Government of the Netherlands and held in Montevideo, Uruguay, November 8-12, provided greater insight into the problems of septoria tritici blotch and septoria nodorum blotch—major constraints within the Southern Cone of South America. Papers presented provided new information applicable, not only to the Southern Cone, but also to many other areas of the world where septoria diseases are a problem. Distributed at this meeting was the newly published manual, *Septoria Diseases of Wheat: Concepts and Methods of Disease Management*, the first in a series of wheat disease manuals planned by CIMMYT.

Wheat Program

The Program's multidisciplinary team consists of 21 international staff at CIMMYT headquarters and 17 posted at locations outside of Mexico. Most staff at headquarters are engaged in germplasm improvement, crop management, and training within the bread wheat, durum wheat, and triticale improvement programs or the support programs that primarily contribute to them. Those working in outreach concentrate mainly on direct support to national agricultural research programs.

Crop Improvement Programs

- Bread Wheat (Mexico)
- Durum Wheat (Mexico)
- Triticale (Mexico)
- Barley (ICARDA/CIMMYT Collaborative Program)
- Winter Wheat (Turkey/CIMMYT Collaborative Program)
- Bread and Durum Wheats for the ICARDA region (CIMMYT/ICARDA Collaborative Program)

The bread wheat, durum wheat, and triticale improvement programs are the core of the Wheat Program. Three additional programs are joint collaborative ventures—one for barley with the International Center for Agricultural Research in the Dry Areas (ICARDA), one for winter wheat with the Government of Turkey, and one for bread and durum wheats in West Asia and North Africa with ICARDA. The germplasm that all six programs develop is distributed to collaborating scientists in national programs through the international nurseries.

Direct Support to National Research Programs

Regional Programs
Support national research programs through consultation, in-country training, and regional workshops and spearhead special efforts such as development of wheat varieties for marginal areas.

- Andean Region
- East/Southern Africa
- South Asia
- Southeast Asia (wheats for more marginal areas)
- Southern Cone of South America (wheats for more marginal areas)

Bilateral Projects
Strengthen wheat research capacity through close, continuous contact with selected national programs over an extended period. Programs with Turkey, Pakistan, and Peru came to a close in 1987.

- Bangladesh
- Turkey
- Pakistan
- Peru

Training
Offers in-service courses (on improvement and production), visiting scientist fellowships, and post- and predoctoral fellowships at Center headquarters.

International nurseries
Nearly 50 nurseries for bread wheat, durum wheat, triticale, barley, and germplasm development serve as direct conduits of germplasm to national programs; information returned by cooperators also helps set priorities and direction of the crop improvement programs.

Support to Germplasm Development

Seven support programs primarily serve the crop improvement programs, but to some degree also supply a wide array of technical assistance to bilateral and regional programs.

Germplasm development
Uses traditional breeding methodologies to produce materials with specific characteristics for use by the bread wheat, durum wheat, and triticale programs.

Germplasm bank
Maintains working collections of breeding materials primarily to support the research of Program scientists and national program collaborators.

Crop management
Counterpart of germplasm improvement that covers six major areas: training, support for nurseries and station management, agronomy of new materials from the breeding programs, stress physiology, agronomic management and pathology, and on-farm trials.

Industrial quality
Screens material so that breeding programs may obtain the variability in quality characteristics required to satisfy national program needs.

Wide crosses
Improves disease resistance and stress tolerance in wheat through interspecific and intergeneric hybridization.

Pathology
Serves the crop improvement programs but also carries out basic research on epidemiology, host-parasite interaction, pathogen variation, and genetics of resistance.

Seed health
Provides a comprehensive and coordinated approach to seed health problems and is responsible for all standard tests for seedborne pathogens in germplasm destined for international distribution.

Economics Research

Because of the variety of challenges researchers must respond to in conducting on-farm research, they are continually called upon to develop new methods to make their work more effective.

For the Economics Program, 1987 was a year of change. Some staff transferred to Costa Rica and Malawi, and others left programs in Kenya, Haiti, and Pakistan to take on new responsibilities outside of CIMMYT. Although the bilateral projects of the Center's Maize and Wheat Programs in Pakistan came to an end in 1987, an economist continued to be based in a bilateral program with Pakistan to work with staff of the national program to help strengthen the capacity of economists in the research system.

The predominance of change in 1987 did not mean that our research agenda received less attention. Work continued in five main areas (see box, page 51), each of which is featured in the following sections: technology design and evaluation, policy issues in technology utilization, commodity sector and policy analysis, research resource allocation and research impacts, and training.

Technology Design and Evaluation

The Economics Program has collaborated intensively with national programs in formulating, demonstrating, and institutionalizing procedures for on-farm research. Work in all of those areas continued in 1987.

On-farm research—With staff of the Maize and Wheat Programs, we contributed to numerous on-farm research programs conducted by national program scientists. Mexico's National Institute of Forestry, Agriculture, and Livestock Research (INIFAP), with input from CIMMYT Economics staff, continued on-farm research projects at several sites in the southern zone. At La Fraylesca, Chiapas, three verification/demonstration trials of a recommendation on liming soils were harvested in 1987. An analysis of the results showed a yield increase of 1.44 t/ha from the application of 2 t/ha lime. The marginal rate of return to liming, including future residual effects, is 400%, compared with a cost of capital of 80%. (The marginal rate of return indicates what farmers can expect to gain in return for their investment when they adopt a new practice—in this case, liming.)

At another site in La Huerta, Jalisco, a second cycle of on-farm trials was planted in 1987. Results of the first cycle of exploratory experiments showed that rainfall distribution is a critical factor in explaining farmers' fertilizer management practices.

A diagnostic study and two cycles of trials have been conducted in the Nakhon Sawan study area of Thailand. Results from the first cycle support the hypothesis that applying urea is profitable whereas applying compound fertilizer is not, because there is no response to phosphorus or potassium.

Researchers of the Ghana Grains Development Project, with the aid of a visiting staff member of the Economics Program, developed a questionnaire for a survey in Ejura District, an important maize production area located in Ghana's transition zone between the forest and savanna. The survey is designed to examine maize and cowpea practices in the major and minor rainy seasons, as well as the availability and use of certain inputs, including seed and fertilizer. The project also continued to assess the adoption of recommended maize production practices in a study area of Ghana's Brong-Ahafo Region.

In Haiti the on-farm research program has moved into a new area, Petit Goave, with a more complex farming system in which maize, sorghum, and pigeon pea are grown on steep hillsides. A first cycle of zero tillage and erosion control trials was evaluated, and preliminary results indicate a 26% yield difference between the farmers' practice, burning, and the alternative practice, mulching.

Developing methods—Because of the variety of challenges researchers must respond to in conducting on-farm research, they are continually called upon to explore and develop new methods to make their work more effective. For example, in a study of maize-based farming systems in northern Pakistan (see box, page 46), researchers developed methods to value green and dry fodder in order to assess the relative importance of grain and fodder in the farming system.

Another issue with methodological implications for on-farm research is the economic valuation of long-term effects, such as nutrient carry-over, specific effects of changes in cropping patterns on the physical condition of the soil, and tillage or weed control strategies requiring more than one cycle for a payoff to occur. The need to assess those effects is becoming more urgent as the continuing health of the ecological environment in which agriculture is practiced becomes a greater concern. In 1988 we will begin to review the main methods and concepts involved in the economic analysis of long-term effects.

Institutionalizing on-farm research—A clear explanation and demonstration of on-farm research methods is especially important in countries where research administrators and scientists are considering how to adapt those procedures to their own institutional settings. In the Central America and Caribbean region, the institutionalization of on-farm research within national programs has long been an important activity of the Economics Program, and it gained new impetus in 1987 with the design of an Inter-American Institute of Agricultural Sciences (IICA) project sponsored by the United Nations Development Programme (UNDP). The project's two interrelated goals will be to establish on-farm research on basic grains within the national programs of the region and to reinforce collaboration in on-farm research among them. CIMMYT's two economists for Central America and the Caribbean are now based in Costa Rica, where they will support the project by developing and offering training in on-farm research procedures throughout the region.

We also continue to explore issues related to the institutionalization of on-farm research. Perhaps one of the most crucial issues is how to strengthen linkages in national research systems between commodity programs and disciplines for both applied and adaptive research. A principal contribution of the farming systems perspective in agricultural research is its potential to do just that: it fosters an explicit farmer orientation in research through strong links between researchers and farmers and often implies that other links in the research system between commodities and between disciplines must be strengthened as well. However, the solution to strengthening those linkages is not necessarily to create a new on-farm research unit. Often it is more effective to improve communication across commodity and disciplinary programs within the existing organizational structure.

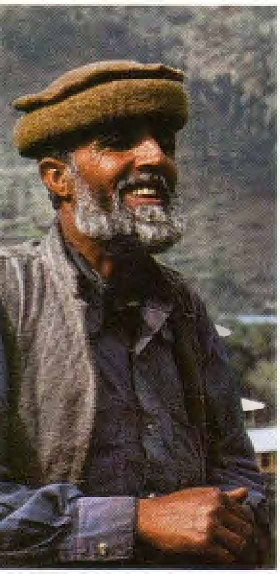
Policy Issues in Technology Utilization

The Economics Program's second major area of work focuses on policy issues related to technology utilization. Many policies—on the delivery of fertilizer or seed, marketing systems, credit, or extension—influence the potential utilization of new technologies generated through adaptive research. But adequate farm-level information is not always available to policymakers when they take decisions that impinge on input and marketing systems.

At least two types of information can be provided by an agricultural research system with a strong farmer orientation: 1) technical information related to physical and biological responses under farmers' conditions, and 2) information on institutional constraints to the effective use of appropriate technology at the farm level. For example, the presentation of results from on-farm experiments and surveys to policymakers and input suppliers has led to changes at the local level in credit policy in Panama and has pointed the way to reforms in marketing fertilizer in Haiti and Mexico.

In 1987 studies undertaken over two years in Pakistan were used as a basis for recommendations aimed at reducing the possibility of a rust epidemic. Since the Green Revolution, Pakistani farmers have been slower than their counterparts in ecologically similar areas, such as the Indian Punjab or Mexico, to switch from one improved variety to another. Furthermore, since large areas in Pakistan were often planted to just one variety, varietal diversity occurred only when farmers made the transition from one dominant variety to another.

Informal surveys of farmers help identify factors limiting farm productivity.



Farmer from Swat Valley, Pakistan.

Joint Production of Maize and Fodder in Maize-based Farming Systems in Northern Pakistan

Several studies undertaken in the irrigated valley of Swat District, the largest maize-producing district in Pakistan, offer a good example of the value of a thorough diagnostic investigation of complex farming systems (for more details, see Byerlee et al. 1987). The farmers in the area followed practices differing sharply from those that had been recommended and extensively demonstrated by research and extension over the past 15 years. They planted maize by the broadcast method at seeding rates greatly exceeding those normally observed for maize and thinned plants continuously throughout the season. To understand farmers' motives for rejecting some of the recommended practices, researchers initiated a series of studies in 1983.

The studies first sought to develop a clear picture of the farming systems in the valley. The dominant characteristic of farmers' resource base was their small farms, which averaged less than one hectare. Certain features of those small farming systems suggested that crop and livestock production would be closely integrated, especially through the use of crop by-products as fodder. Livestock were an important source of income for a significant group of farmers. Forty percent of farmers owned three or more cows or buffaloes, and 22% owned four or more, well above normal subsistence requirements. Livestock numbers had increased over time, and farmers had shifted from cattle to buffaloes, which are almost exclusively stall fed. At the same time, long winters, especially in the nearby mountains, had generated high demand and prices for dry fodder.

The extent and implications of using maize as green and dry fodder were not sufficiently understood by research and extension workers. Maize scientists and social scientists conducted three types of surveys to help clarify those issues. They first monitored a sample of maize fields from planting to harvesting to record plant density/removal at various stages. At each field visit, farmers were asked about the kind and quantity of feed they had given their livestock on the previous day.

A second, informal systems survey was next organized to obtain more information on the role of livestock, fodder calendars, and farmers' criteria for maize management. The third survey, on crop management, was conducted over three consecutive years at maize harvest time to record farmers' management practices in specific fields as well as measure plant density and yields. Some 250 fields were studied.

Those three surveys highlighted the importance of maize as a dual-purpose, grain and fodder crop. Approximately 100,000 plants/ha were removed for green fodder, which, together with dry maize stover, accounted for nearly half the value of production for maize fields. Those figures were even higher for small-scale farmers emphasizing livestock production. Furthermore, it was clear that farmers recognized the tradeoff between grain and fodder production but had evolved a very productive system that provided average grain yields of 4 t/ha in addition to fodder yields. Although the recommended technology yielded 5 t/ha, the increase in yields was not sufficient to compensate farmers for the higher cost of inputs and the value of green and dry fodder they would have to forgo.

Those factors explained farmers' rejection of most of the recommended practices related to seed rate and line planting, as well as their continued use of maize as a dual-purpose crop. The surveys also indicated that the tradeoff between grain and fodder products might be higher for the recommended improved variety, Sarhad White, which was observed to have less density tolerance (that is, a high proportion of barren plants) under farmer management.

The diagnostic surveys provided the basis for identifying research and extension priorities. The subsequent program of on-farm experiments planted under farmer management confirmed nearly all the hypotheses generated by the surveys. Partly due to information from those studies, varietal verification trials and dissemination in the Swat Valley switched from the full-season variety, Sarhad White, to a midseason variety, Azam, which allowed farmers greater flexibility in planting dates and also exhibited density tolerance similar to the farmers' variety. Other components of the recommended package, including the use of phosphorus, were changed to conform with farmers' practices.

Slow varietal turnover and a lack of diversity increase the possibility that rust pathogens will build up or that races will mutate and an epidemic will occur. In Pakistan much of the wheat area was planted to varieties susceptible to rust, with losses estimated at one million tons or more in some years.

The studies indicated a need for more coordination between seed producers and those responsible for setting seed production targets, recommending varieties, and demonstrating new varieties to combat the disease problem. Yield gains from genetic improvement were on the order of 1% per year, at which rate it would be profitable for farmers to change varieties every six years. More effort could be made to promote new varieties to farmers, whose awareness of the disease threat was limited but who cited better yields as their primary reason for changing varieties.

The experiences described above suggest that there is scope for social scientists to improve the flow of information from national agricultural research systems to key decision makers to help accelerate the pace at which technology is adopted. The Program will continue its micro-level policy studies, aimed primarily at decision makers at the local or regional level, in cooperation with social scientists of national programs. Over the next two years, we plan to synthesize and evaluate those case studies for a workshop on farm-based policy research.

Commodity Sector and Policy Analysis

Because research investments often may not yield payoffs for a decade or more, in making decisions maize and wheat researchers in CIMMYT and national programs need to be aware of long-term trends in the wheat and maize economies at the global, regional, and national levels. Our staff regularly collect and analyze data on the production, utilization, and trade of maize and wheat (see following section), some of which are published in the *World Maize Facts and Trends* and *World Wheat Facts and Trends* series. For the latter publication, we are preparing a report on the state of the wheat economy since the Green Revolution, focusing on changes in developing country wheat yields and production, and analyzing trends in selected countries in relation to varietal use, fertilizer application, and cropping patterns.

Potential demand and supply for maize and wheat to the year 2000—To provide information for CIMMYT's strategic planning, we did a preliminary analysis of demand and supply for cereals to the end of the century. Two projections of potential increases in demand to the year 2000 were made for seven categories of cereals: food wheat, feed wheat, food maize, feed maize, milled rice, sorghum and millet, and other cereals (barley, rye, and oats). One projection was based on a conservative scenario for income growth in developing countries and the other on a higher growth scenario.

Overall, the conservative projection indicates an annual growth in demand from 1985 to 2000 of 2.5% for maize and 2% for wheat. Those rates are lower than average annual growth in production from 1950 to 1984, which was 3.6% for maize and 3.1% for wheat. But with the higher growth scenario, annual growth in demand is projected to be 3.6% for maize and 2.6% for wheat.

Will supplies of maize and wheat be sufficient to meet demand? Over the past three and a half decades, the major influences on global cereal supplies have included increased fertilizer use, increased harvested area, varietal improvement, and increased irrigated area (see figure, page 48). Several projections have been made of how some of those factors might continue to affect cereal supplies during the next decade or more.

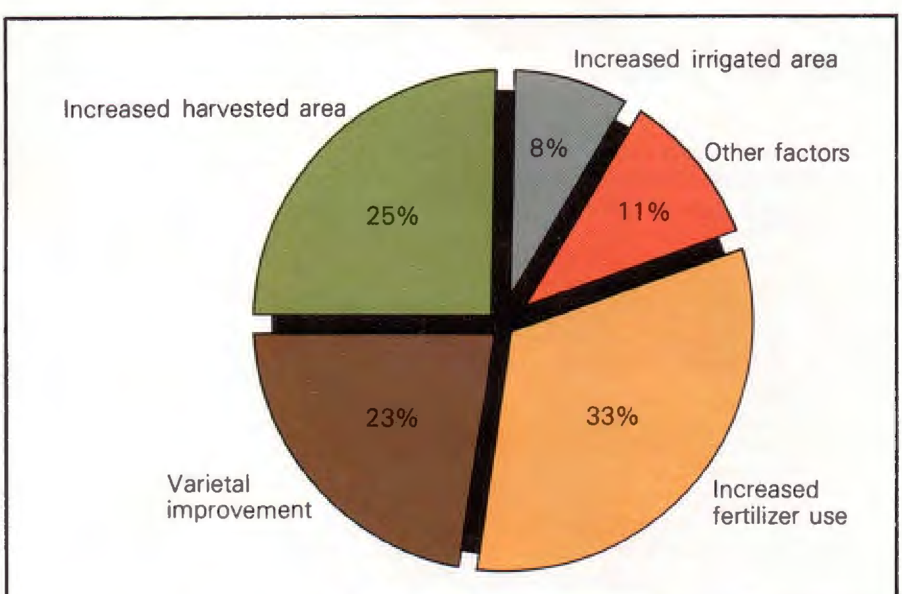
It has been estimated that cultivated area worldwide will expand at about 1.2% per year, but the amount of irrigated land is not expected to increase at the rate once predicted. Fertilizer use, which accounted for about half of the global gains in cereal yields over the past two decades, could still grow considerably, especially in rainfed areas. However, returns to fertilizer in irrigated areas will be lower than in the past because present levels of application are already quite high in many places.

Given those projections, global grain supply is still expected to grow more rapidly than demand over the next decade, thereby contributing to the downward trend in grain prices. This seemingly favorable outlook belies the fact that in some regions access to grain will be limited. Developing country imports of maize and wheat are predicted to grow

There is scope for social scientists to improve the flow of information from national agricultural research systems to key decision makers to help accelerate the pace at which technology is adopted.

strongly during the remainder of the century, and self-sufficiency is projected to fall in all of the world's major regions. The most exceptional growth in demand for imports is likely to occur in Africa, although many African countries may lack foreign exchange to import cereals. Some Asian countries that are presently close to self-sufficiency in cereals are likely to become significant importers once again, especially of maize for feed.

Though many uncertainties surround those projections, their basic message is that growth in real incomes is a critical determinant of future demand. If incomes do not recover to the rates of growth seen during the late 1960s and the 1970s, demand for cereals will slow to the year 2000. In that case it is probable that global demand can be met from increases in supply. But should economic growth rates recover to the level of the 1970s, the world will experience sizeable upward pressure on demand for cereals and, ultimately, on real grain prices. In any case the analysis of supply and demand emphasizes that, if the poor are to receive the major benefits of agricultural research, it is necessary to focus research on regions where maize and wheat are important in the incomes of poor producers or diets of poor consumers.



Factors contributing to increases in the global supply of cereals, 1950-1985 (percentage of total increase).

Future commodity studies—In the future the Program will seek to collaborate with national program researchers in evaluating the utility of commodity sector studies to research managers. Those studies are probably most useful when rapid changes in supply and demand occur or when the maize or wheat sector undergoes significant policy reforms that have implications for future payoffs to research. The development of rapid, low-cost methods for commodity sector analysis might be one possible contribution of such studies.

Research Resource Allocation and Research Impacts

CIMMYT devotes a small but increasing amount of time to analyzing the allocation of research resources and to evaluating the productivity and impact of research. That set of activities, which takes place mainly, but not exclusively, in the Economics Program, aims to provide information and analysis to managers both in national research programs and in CIMMYT itself, and to develop appropriate methods for national programs to study these issues.

Research resource allocation—Research managers are compelled to rationalize the allocation of resources to meet multiple and sometimes conflicting goals. We seek to provide agricultural administrators with information and analytic tools to help in making decisions about the distribution of scarce funds and personnel among competing crops in a zone or between zones for a given crop. Work to date has used the techniques of domestic resource cost analysis to determine the profitability at the farm and national levels of alternative crops or production techniques (see box). Those methods are especially appropriate when price policy distortions hide the underlying comparative advantage of a crop or production technology in a region or country.

In 1987 we continued studies in research resource allocation and, in conjunction with the Coarse Grains, Pulses, Roots, and Tubers Center (CGPRT) in Bogor, Indonesia, helped organize a workshop entitled "Research Resource Allocation and Comparative Advantage." The three-week workshop, sponsored by the European Economic Community (EEC), brought together senior research managers and analysts from six Asian countries and a number of resource persons from universities and development organizations around the world. It was designed to explore alternative ways to decide

Comparative Advantage and Policy Incentives for Wheat Production in Zimbabwe

Between 1965 and 1975, rapid growth in wheat production transformed Zimbabwe from a net wheat importer to a net exporter. However, domestic production has not kept pace with demand, and renewed wheat imports have drained scarce foreign exchange and heightened concerns about the erosion of national food security. The question of whether or not wheat production should be continued and/or expanded thus assumes critical importance in the food policy debate.

In 1987 we undertook a study (see Morris 1987) to establish whether or not Zimbabwe enjoys a comparative advantage in wheat production and to assess the effects of government policies on producer incentives. (Comparative advantage is an expression of the efficiency of using local resources to produce a particular product—in this case, wheat—when measured against the possibilities of trade.) Resource cost ratios were calculated for six major commercial crops—wheat, maize, soybeans, groundnuts, cotton, and tobacco—under several scenarios in which land and/or water limited crop production to determine which crops represented the most efficient use of domestic resources.

Preliminary results of the study suggested that present agricultural policies provide incentives for commercial farmers to allocate scarce resources efficiently (in most cases to tobacco and cotton). Results of the study also revealed how government policies affect the economics of farming, sometimes positively, as in the case of subsidized agricultural credit programs, but more often negatively, as in the case of controlled producer prices, taxes on inputs, and wage policies.

One important finding is that wheat production is an efficient use of Zimbabwe's resources when water is plentiful. But in times of drought, when farmers must choose between irrigating wheat and irrigating other crops, it is more efficient to use water on tobacco, then cotton, and then maize. An implication of this finding is that the government might consider relaxing its policy of requiring farmers who receive loans from the National Farm Irrigation Fund (NFIF) to grow wheat even during times of drought if that means that they will not have enough water to irrigate tobacco.

How are future changes in world prices likely to affect Zimbabwe's current pattern of comparative advantage? The profitability of the six irrigated crops was recalculated using projected future prices for the year 2000 for outputs and fertilizers. The results suggested that future developments in global commodities markets probably will not eliminate Zimbabwe's present comparative advantage in producing tobacco and cotton. Although past forecasts of world commodity prices have often been inaccurate, the fact that tobacco is nearly ten times as profitable as the highest ranking grain, and cotton nearly five times as profitable, suggests that relative prices at the global level would have to change a great deal to displace these traditional export crops.

But to the extent that future political developments in South Africa have economic consequences, Zimbabwe's current structure of comparative advantage could change. Further restrictions on trade and transit through South Africa would considerably affect the agricultural sector by influencing the availability and prices of imported production inputs, the prices received for agricultural exports, and those paid for food imports. When high rail freight costs for imports and exports were used to simulate the likely effects of trade restrictions, the profitability of wheat production relative to that of other crops increased, indicating that a shift in production patterns might be appropriate should access to a deep-water port become restricted. In that case it would probably make economic sense for Zimbabwe to strive for higher levels of self-sufficiency in wheat, presumably through a combination of policies to enhance production and manage consumption.

upon the allocation of research resources and also to explore practical means for using economics concepts in taking those decisions. Participants focused on situations in which research managers had to choose among a few well-defined alternatives in making fairly major judgments on research strategy.

Over the next two years, we will be alert for requests to analyze specific questions of research resource allocation. The major clients for such work are regional research directors seeking to evaluate the allocation of resources across commodities within a region or national maize and wheat research coordinators responsible for allocating resources to maize and wheat across regions. The Program will be more flexible in the techniques used to analyze questions of that nature and will actively involve national program scientists and economists in those studies.

More precise information on the role of wheat and maize in the diets of Third World consumers will contribute to a better understanding of the impact of research.

Evaluating the productivity and impact of research—During 1987 the Program took preliminary steps to establish a new program, to be initiated in 1988, on the impacts of agricultural research. It will be devoted to better understanding the impact of research, especially CIMMYT's, on the poor. Equity issues are often complex, involving an analysis of the implications of new technology for landless rural people, of the use of new technology by small-scale farmers (especially in marginal areas), and of how price changes affect poor consumers. As a starting point in studying the distributional consequences of new maize and wheat technologies, CIMMYT will assemble better information on the roles of maize and wheat in the incomes of poor producers and the diets of poor consumers in major maize- and wheat-producing countries.

Training

In addition to the in-service training program at headquarters, where instruction on the economic analysis of agronomic data is offered, the regional and bilateral programs held many workshops and courses in 1987 on a range of topics, including various social science components of on-farm research. Two workshops sponsored by the Mexican bilateral program and INIFAP focused on the economic analysis of experimental results. A regional workshop on research resource allocation is discussed earlier in this report.

Training in on-farm research offered by CIMMYT agronomists and economists is often integrated with the research itself, a characteristic that is especially true of the call system courses, whose participants design and evaluate trials. In the eastern and southern Africa region, call system training extending over several crop cycles was completed in Ethiopia, Kenya, Zambia, and Malawi. Similar courses were offered at selected locations in Latin America. This formal training was supplemented through informal training during tours and reviews by CIMMYT staff and in the normal course of work with national program researchers.

Economics Program

Economics Program staff are primarily concerned with developing and teaching research methods that range from methods for conducting on-farm research and exploring policy issues in technology utilization, to the economic analysis of research priorities and impacts. Considerable time is also devoted to commodity sector and policy analysis. The work of seven international staff in regional and bilateral programs is integrated with the research and training done by the four staff at headquarters.

Support to National Research Programs

Regional programs
Strengthen the capacity of national programs in the developing world to conduct efficient agricultural research by working with national program scientists to formulate, refine, test, and impart research methods. Focus on particular regional needs through training, workshops, and consultation with national programs.

- Central America and the Caribbean
- Eastern and Southern Africa
- Southeast Asia

Bilateral programs
Collaborate closely with social and biological scientists in particular countries to strengthen social science capacity within each national program.

- Haiti
- Mexico
- Pakistan

Training
Offer training in economic analysis to maize and wheat in-service trainees; provide (with staff of the Maize and Wheat Programs and national programs) in-country training in on-farm research; and offer workshops and short courses on a range of topics, including research resource allocation and diagnosis and planning in OFR. Arrange pre- and postdoctoral fellowships and fellowships for visiting scientists from national programs to work on projects of special interest to their program and to CIMMYT staff. Develop manuals and other materials to support training activities.

Areas of Work

Four areas of research are undertaken in support of national programs and to provide CIMMYT managers and scientists with better information for setting research priorities. Some activities—commodity sector analysis for the *Facts and Trends* series is one example—that were once solely within the purview of headquarters staff are now part of the responsibilities of outreach staff as well. And as much as possible, staff from headquarters travel to regional and bilateral programs to collaborate with outreach economists on specific projects.

Technology design and evaluation
Develop, demonstrate, and institutionalize methods for on-farm research. Interact with plant breeders on varietal development issues.

Policy issues in technology utilization
Provide policymakers with information to make more effective decisions on policies, such as the provision of inputs or credit, which influence technology utilization.

Commodity sector and policy analysis
Collect and analyze data to understand long-term trends in the wheat and maize economies at the global, regional, and national levels as a basis for setting the maize or wheat research agenda for CIMMYT and its regional and bilateral programs.

Research resource allocation and research impacts
Provide agricultural administrators with methods to help in allocating resources within research systems; analyze the returns to agricultural research and its distributional impacts.

Support Services

Countries of origin of participants in the in-service experiment station management course, 1987

	Maize	Wheat
Africa		
Ghana	1	-
Kenya	1	-
Morocco	-	1
Somalia	1	-
Tunisia	1	-
Uganda	1	-
Total	**5**	**1**
Asia		
Indonesia	1	-
Malaysia	1	-
The Philippines	1	-
Thailand	1	-
Turkey	-	1
Vietnam	1	-
Total	**5**	**1**
Latin America		
Brazil	1	-
Costa Rica	1	-
Ecuador	1	-
Guatemala	1	-
Mexico	1	1
Panama	1	-
Paraguay	-	1
Venezuela	1	-
Total	**7**	**2**
Total trainees	**17**	**4**
Total countries	**17**	**4**

Because information and data processing cut across all of CIMMYT's activities, some issues pertaining specifically to these support services are being addressed in the strategic plan. We also anticipate that the research and training strategies emerging from our discussion of many other issues will have significant implications, not only for information and data processing, but for experiment station management and laboratories as well. That is a necessary consequence of their integral role in the Center's work at headquarters and of their tendency to reach beyond it, affecting nearly all of our cooperators in developing countries.

Experiment Stations

In Mexico the primary responsibility of experiment station management is to oversee field operations on some 500 ha of land at various research stations and other experimental sites. The unit works closely with CIMMYT scientists and helps in many ways to reduce their burden of day-to-day field supervision. Most of that work takes place at five stations in Mexico, four of which (El Batán, Poza Rica, Tlaltizapán, and Toluca) are managed directly by Center staff and the fifth (at Ciudad Obregón) by Mexico's National Institute for Agricultural, Livestock, and Forestry Research (INIFAP).

At the four stations under our direct supervision, we installed automated, electronic equipment this year for recording weather data. At those same stations, we conduct research to ensure that variation in the field is kept to a minimum, so that researchers can distinguish maize and wheat genotypes accurately. Among the current station research projects are fertilizer and herbicide trials at Poza Rica and Toluca, a weed survey and soil studies at Tlaltizapán, and a comparison of tillage methods at El Batán. An important by-product of that research is the development of techniques that can be taught in experiment station training courses.

Training in experiment station management is offered both at headquarters and other locations around the world. In our in-service course, which is held once a year in Mexico (see table), workers from developing countries spend about five months studying and gaining experience in the whole range of activities that are involved in running an experiment station. This year we also provided training in Ecuador, Kenya, Panama, and Paraguay and consulted with the staff of experiment stations on special problems in the latter three countries plus Malaysia, Turkey, and Vietnam.

General Laboratories

CIMMYT has two general service laboratories: one concerned with cereal chemistry and the other with soil and plant tissue analysis. In the former we assess nutritional quality of cereals, with special emphasis on quality protein maize. During 1987 about 16,600 samples were tested for various parameters indicating protein quality, and the results were used by the breeding program in selection. In addition, we began a joint study with breeders this year to compare the protein quality of normal populations with that of quality protein maize (QPM) at different stages of development. Special emphasis was given to nutritional evaluation at the green maize stage, since this product is widely consumed in some developing countries. So far, it has been found that QPM not only has a better amino acid balance at the green maize stage but high protein digestibility as well. Electrophoretic tests of maize proteins were also initiated to identify genetic material of interest to breeders. Four national program researchers were trained in the cereal chemistry laboratory during this year.

The soil and plant tissue laboratory serves the Maize, Wheat, and Economics Programs as well as the experiment stations and training programs. During 1987 we tested about 1400 plant tissue samples and conducted chemical tests for micro- and macroelements in 1600 soil samples. Physical tests were also done on some soil samples.

Staff of the two support laboratories also evaluate genetic and segregating materials used by the Wheat and Maize Programs in selecting germplasm that is tolerant to the high levels of aluminum often found in acid soils of the humid tropics. In 1987 we evaluated 350 samples for the Maize Program and 3700 samples of segregating materials for the Wheat Program.

Information Services

The Information Services unit consists of three interrelated groups: publications, the scientific information unit or SIU (which includes our specialized library), and audiovisuals development. Their primary objective is to assist CIMMYT 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 amount of emphasis given to each of those activities will depend very much on the outcome of the strategic planning process, during which we are examining issues such as the categories of information products that the Center should be developing and its efforts to increase the availability of scientific information to national programs. There is likely to be increased emphasis on various categories of technical and practical information (as opposed to more general, descriptive information about CIMMYT activities), since in our discussions with national program representatives this year, they expressed an unequivocal preference for more of the former. We can help meet that demand with publications such as *The Septoria Diseases of Wheat* and *Insect Pests of Maize*, which were among the 66 titles produced by the unit this year (see list on page 81).

It is also probable that the Center will continue strengthening its systems for helping colleagues in national programs gain better access to scientific literature. That service will become more necessary as the costs of maintaining journal subscriptions rise and more efficient as the capabilities of bibliographic information technologies grow and their costs come down. We saw a number of indications this year of increased demand for our services (document delivery, database searches, and so forth) and took various steps to increase their efficiency and cost-effectiveness. The most noteworthy was to acquire the BASIS text management system and, using that software, to automate various library functions, with assistance from the Data Processing unit (for details see Extra-Core Grants section). We also obtained the CDS-ISIS package developed by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and adapted it in such a way that it can be used on IBM PCs to document personal literature collections.

Data Processing

This unit provides vital support in all the major areas of CIMMYT's operations, including research, administration, information services, accounting, and experiment station management. Its chief contributions are to consult with staff on statistical analysis, develop new software, install and attend to the operational aspects of computer hardware, and assist computer users. Software development is the main task of our crop systems group, to which one programmer was added in 1987. Another new staff member joined the operations unit, which is responsible for hardware maintenance and assistance to computer users.

The crop systems group made some modifications in the original design of the wheat pedigree management system completed in 1986. Completion of that software has paved the way for other products that will form part of an overall wheat system, with the pedigree management system as its nucleus. Much work also went into the Maize Program's Maize Germplasm Bank Inquiry System, which contains passport, regeneration, and storage data on all of CIMMYT's maize accessions and can be enlarged as new data are gathered through evaluations of these materials. In an effort to make that information widely available to national programs, we initiated a project, with funding from the Technical Centre for Agricultural and Rural Cooperation (CTA) of The Netherlands, for placing the portion of the database containing passport data on CD-ROM (compact disc, read-only memory), which is mentioned in the section on the maize germplasm bank, page 23. CTA will later provide selected national programs with equipment for reading the compact disc.

Another important activity in our work on software was to support the library/SIU in employing BASIS software for various library functions and adapting the CDS-ISIS package for use on IBM PCs to document personal literature collections. We also completed the development of a database for keeping track of former CIMMYT trainees.

The operations group is preparing to upgrade CIMMYT's computing capacity by replacing our VAX 780 and 750 with two microVAX IIIs. During 1987 the group was also busy installing some 35 new IBM PCs, educating users in the use of computer equipment, and expanding the local area network set up last year, which includes PC and VAX terminals and will permit much better use of computer resources.

In strategic planning we are examining issues such as the Center's information product mix and efforts to increase the availability of scientific information to national programs.

Extra-Core Grants

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

- Direct assistance (posting staff or providing 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 Center's Board of Trustees has established the following guidelines for judging the relative merit of projects to be financed 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 1987 extra-core grants amounted to US$5,144,000 or 18% 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 significantly to the Center's research programs.

Maize

Project:	**Ghana Maize Program, Phase II**	
Donor:	Canadian International Development Agency (CIDA)	
Pledge:	CA$4,977,866 (US$3,771,000 est.)	
Duration:	October 1983 to March 1989	
Financial Summary	Expenses (US$):	
	Previous years	$2,245,000
	1987	$ 615,000
	Total to date	$2,860,000
	Balance available	$ 911,000

Objectives—This project was initiated to improve maize and grain legume production in Ghana 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 periodically visit the project to assist with on-farm research. The International Institute of Tropical Agriculture (IITA) participates in the research on grain legumes.

Activities in 1987—The maize improvement program continued efforts begun in 1986 to 1) consolidate its array of pools and populations and 2) develop inbred lines from an advanced population. A number of variety trials were conducted at experiment stations, along with various international trials, many of which were affected by drought.

Maize agronomists are focusing on intercropping of maize and cassava. Trials grown in 1987 dealt with a range of questions (the response of the intercrops to fertilizer, the effect of spatial arrangements on yields, and so forth); from the results recommendations for small-scale farmers will be developed that should help them increase economic returns from this cropping system.

In connection with both the maize improvement and agronomy programs, hundreds of on-farm research trials and extension demonstrations were distributed. The project also continued to offer diverse training opportunities, including scholarships for degree training, courses at CIMMYT and IITA, and in-country training for approximately 800 extension officers.

Maize and Wheat

Project:	**East Africa Cereals Program**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	**Maize** CA$ 1,760,000 (US$1,284,000 est.)
	Wheat CA $983,000 (US$754,000)
Duration:	October 1984 to June 1988
Financial Summary	**Maize** Expenses (US$): Previous years $ 647,000 1987 $ 416,000 Total to date $1,063,000 Balance available $ 221,000
	Wheat Expenses (US$): Previous years $ 348,000 1987 $ 253,000 Total to date $ 601,000 Balance available $ 153,000

Objectives—The principal objective of this program is to strengthen the maize and wheat agronomy research capacity of the national programs of Burundi, Ethiopia, Kenya, Rwanda, Somalia, Tanzania, and Uganda. Toward that end project staff offer consultation and training in each country and support regional initiatives such as workshops. In-country training is often conducted in cooperation with Economics Program staff and with other development organizations operating in the region.

Maize activities in 1987—The two agronomists staffing the maize portion of this project responded through various in-country and regional activities to the needs of national programs. In several countries they evaluated experiment station and on-farm trials, assisted with in-country training, and helped procure equipment. In Tanzania they took part in the national program's annual research reporting and planning session, and in Kenya they looked into the possibilities of cooperative work on the parasitic weed *Striga*, a widespread problem in maize and sorghum that needs to be dealt with by both agronomists and breeders.

At a four-day session in Ethiopia, staff helped address the issue of linkages between on-farm and experiment station research on maize, wheat, and other crops. They also helped conduct a regional workshop there on the analysis and interpretation of agronomic data and use of MSTAT software on PCs. All of the 16 participants brought their own data sets for analysis and became quite proficient, even though many had never before touched the keyboard of a PC. Some of the data they analyzed were as much as five years old, indicating that the lack of computer equipment and training in its use are serious bottlenecks in some programs and that as a consequence they are unable to base the planning of future research on adequate analysis of past data.

Wheat activities in 1987—The project agronomist and a core-funded pathologist were relocated from Nairobi to Addis Ababa. Since arriving in Ethiopia, the agronomist has spent most of his field time visiting research centers of the Institute of Agricultural Research at Holetta, Kulumsa, Adet, and Sinana. The agronomist also made consultative visits to Kenya, Uganda, Somalia, Burundi, Rwanda, and Tanzania.

Various workshops were conducted throughout the region in 1987. The biennial East African Regional Wheat Workshop was held October 5-10 in Antsirabe, Madagascar (see Wheat Research section for details). In Ethiopia a training course that covered technical aspects of agronomic research with an emphasis on on-farm research was held for 49 agronomists of the Institute of Agricultural Research. In Uganda 18 participants from practically every discipline in the country's research organization attended a workshop that covered on-farm research, socioeconomic considerations, agronomic assessment of farmers' fields, and identifying research themes. In Somalia 15 staff members of the country's Agricultural Research Institute participated in a training workshop on herbicide theory and application technology.

Wheat

Project:	**Bangladesh Wheat Program**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 4,680,000 (US$3,744,000 est.)
Duration:	April 1982 to June 1988
Financial Summary	Expenses (US$):
	Previous years $2,181,000
	1987 $ 321,000
	Total to date $2,502,000
	Balance available $1,242,000

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 the research and production staff of the Bangladesh Agricultural Research Institute's wheat program.

Activities in 1987—Lower than estimated wheat area and yields resulted in a severe production shortfall, which caused special concern, since it was coupled with lower than expected yields from the preceding rice crop and whole-spike sterility of wheat crops in localized areas. The report of a consulting micronutrient specialist indicated that the sterility problem may be due to micronutrient stress, perhaps boron in particular.

Funds were advanced to the national program to train cooperators that are conducting demonstrations with the Extension Varietal Demonstration Kit, which has been an important vehicle for varietal promotion and is partly responsible for significant expansion of the variety Kanchan into wheat land previously occupied by the variety Sonalika. Kanchan will occupy an estimated 20-25% of the wheat area in the 1987-88 season.

Wheat

Project:	**Peru National Cereals Program**
Donor:	Peruvian National Institute for Agricultual Research and Production (INIPA) and World Bank
Pledge:	US$482,000
Duration:	August 1983 to December 1987
Financial Summary	Expenses (US$):
	Previous years $394,000
	1987 $ 89,000
	Total to date $483,000
	Balance available $- 0 -

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

Activities in 1987—On-farm agronomic research activities were consolidated at a workshop held in Puno. Participants from many regions summarized their experience to date and presented detailed results from the most recent crop cycle and plans for future experiments. Artificial inoculations of stem and leaf rusts were initiated in breeding nurseries during the winter coastal cycle to identify germplasm with adequate levels of resistance. The first Peruvian triticale variety, Atahualpa, was released for the Cajamarca region, and a production trainee was supported by CIMMYT. The project was terminated in December.

Summary of project accomplishments—The project's major accomplishment was the consolidation of several isolated breeding efforts in the highlands into one coordinated program. This freed manpower and resources for on-farm agronomic work, which expanded significantly during the project's four and a half years. In addition, a wheat industry was established in the coastal valley of Majes, where cultivation rose rapidly to 3500 ha in 1987. Average yields now exceed 4 t/ha. In the Peruvian high plateau (3800 masl), agronomic practices for wheat production without irrigation were introduced.

Wheat

Project:	**Wheat Improvement in Turkey**
Donor:	United Nations Development Programme (UNDP)
Pledge:	US$380,000
Duration:	December 1983 to March 1987
Financial: Summary:	Expenses (US$): Previous years $391,000 1987 ($ 11,000) Total to date $380,000 Balance available $- 0 -

Objectives—The project sought to strengthen the National Winter Cereal Research Project in Turkey with the aim of improving and stabilizing small-grains production.

Activities in 1987—This project terminated in March and a final report for the duration of the project (since March 1984) was submitted.

Summary of project accomplishments—During the project introduced material (winter and spring types of bread and durum wheats, barleys, and triticales from around the world) was evaluated in appropriate environments, and the best wheats were selected for use in the Turkish National Cereal Improvement Program. One winter wheat variety, Hawk, from Colorado performed very well, and commercial quantities were imported by the government of Turkey for distribution in eastern regions. Regular exchange of material with programs around the world has been intensified. Sources of resistance to tan spot were introduced from Australia and Minnesota, USA. Fourteen young scientists attended in-service training courses at CIMMYT during the project. Ten senior scientists visited CIMMYT and other programs to update their knowledge of advances in breeding and germplasm development. During two traveling seminars, researchers from various countries reviewed progress in the development of Turkish spring and winter wheat and barley germplasm.

Wheat

Project:	**Barley Yellow Dwarf Virus (BYDV)**
Donor:	Italy
Pledge:	US$1,477,000
Duration:	January 1984 to December 1987
Financial Summary	Expenses (US$): Previous years $ 618,000 1987 $ 517,000 Total to date $1,135,000 Balance available $ 342,000

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 1987—The trapping of live aphids, using Rothamsted suction traps, has shown that the main aphid vector at El Batán is *Metopolophium dirhodum* and that approximately 40% of these are transmitting a MAV-like isolate of BYDV. ELISA was used to test leaf samples from plants suspected of being infected with BYDV from different areas of Mexico. An international workshop on BYDV was held in Udine, Italy (see the section on wheat research for details), with the help of Professor Elvio Refatti and his local committee. And in 1987 yield testing was begun under controlled inoculation of cereal lines that exhibit symptomatic resistance to BYDV.

Wheat

Project:	**Introduction of Alien Genes into Wheat through Conventional and Biotechnology Approaches**
Donor:	Australia, UNDP
Pledge:	A $190,000 US$149,000
Duration:	Australia, multiyear; UNDP, negotiated annually
Financial Summary	Expenses (US$): Previous years $ 89,000 1987 $ 40,000 Total to date $129,000 Balance available $ 20,000

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 tolerances (salt, drought, aluminum, and copper) from related genera into wheat.

Activities in 1987—An evaluation was conducted of the role of some cytogenetics systems in alien genetic transfers for *Triticum aestivum* improvement. The systems included: 1) use of the 5B mechanism for enhancing F_1 hybrid recombination events, 2) development of "partial" or "complete" synthetic genomes, 3) induced translocation production, and 4) callus culture for aiding gene transfers. Diagnostic applications included the techniques of polyacrylamide gel isoelectric-focusing and conventional polyacrylamide or cellulose acetate gel electrophoresis. This has facilitated the establishment of numerous isozyme variations among several alien species. International bread wheat nurseries were analyzed for the 1B/1R translocation through applications of glucose-phosphate isomerase isozyme. The year's activities led to eight scientific articles on the above topics.

Maize, Wheat, and Economics

Project:	**Pakistan Maize, Wheat, and Economics Program**
Donor:	United States Agency for International Development (USAID)
Pledge:	**Maize** Rps. 6,922,397 (US$ 556,000 est.) US$ 484,000
	Wheat Rps 9,499,286 (US$ 702,000 est.) US$ 732,000
	Economics Rps 11,772,524 (US$ 684,000 est.) US$ 658,000
Duration:	**Maize and Wheat** October 1984 to September 1990
	Economics October 1984 to September 1990

Objectives—The overall objective of this project, which grew out of previous work by USAID and the Pakistan Agricultural Research Council (PARC), is to increase the availability of improved agricultural technology to farmers through research and various activities aimed at strengthening the country's capabilities in maize, wheat, and social science research. The economics component of the project was added in 1984 and, like the maize and wheat components, is managed by one CIMMYT staff member.

Maize activities in 1987—The maize specialist in the project continued to provide training and other assistance as part of an overall effort to promote a more integrated, multidisciplinary, problem-oriented approach in the national maize program. His efforts to strengthen linkages between maize breeding, agronomy, and economics and his involvement in on-farm research were tied closely to activities of the CIMMYT Economics Program. Apart from that work, he was involved in various aspects of germplasm development, agroecological analysis, and mechanization of maize production.

Financial Summary	Maize	
	Expenses (US$):	
	Previous years	734,000
	1987	174,000
	Total to date	908,000
	Balance available	132,000
	Wheat	
	Expenses (US$):	
	Previous years	$ 885,000
	1987	$ 327,000
	Total to date	$1,212,000
	Balance available	$ 222,000
	Economics	
	Expenses (US$):	
	Previous years	$ 128,000
	1987	$ 131,000
	Total to date	$ 259,000
	Balance available	$1,083,000

Summary of maize accomplishments—Although some funds remain for maize training and other activities, the maize component of this project essentially came to a close in 1987. Its effects on maize improvement were perhaps most strongly felt at the National Agricultural Research Center (NARC) and in the state of Azad Jammu and Kashmir. National maize breeders are now better placed to meet the challenges of developing a cost-effective hybrid program that is closely integrated with the current population improvement scheme and of developing early maturing maize and materials with improved tolerance to cold and other environmental stresses. The participation of the maize specialist in on-farm research was most effective in Northwest Frontier Province (NWFP). And in general, the national program benefitted considerably from in-country courses and various training activities at CIMMYT headquarters.

Formidable obstacles to improved maize production remain, however, notably the poor quality and limited availability of improved seed and agricultural machinery. Maize research will no doubt be a part of the solution to those problems, but it cannot remove them alone. Suggestions as to how seed production and other issues might be addressed were presented in an end-of-tour report prepared at the close of the maize portion of the project.

Wheat activities in 1987—Thirty-eight national and 10 international scientists went from Multan to Peshawar, April 4-11, during a wheat traveling seminar. A review of the CIMMYT component of the Management of Agricultural Research and Technology (MART) project was held June 16 at PARC in which provincial and PARC/NARC scientists and administrators participated. Although funds remain for training and consulting, the wheat component of the project ended in September, and a detailed termination report was submitted.

Summary of wheat accomplishments—In the course of this three-year project, the wheat agronomist assisted various wheat programs in the country with mechanizing the planting and harvesting of on-station breeding materials, training wheat breeders in herbicide use, strengthening the national uniform yield trial nurseries, and strengthening the Kaghan Wheat Nursery. Six researchers were sent for seven months of practical wheat breeding and pathology training at CIMMYT. Six national staff participated in breeding-related scientific meetings, and six visiting scientists traveled to Mexico to discuss various programs and to develop collaborative projects.

As CIMMYT ends it formal ties with the Pakistani wheat programs, the country's wheat breeding situation is encouraging. National scientists have the ability to develop good materials that can help increase and stabilize local wheat production. However, the good work of breeders is being nullified by a very slow seed replacement and distribution system. Many farmers are still using banned disease-susceptible varieties and their own seed, with major implications for the effort to stabilize wheat production in Pakistan. For background on the Wheat Program's 25-year association with Pakistan, see the section on wheat research.

Economics activities in 1987—Although CIMMYT's Maize and Wheat Programs terminated their work in this project this year, Economics Program staff continue to participate, concentrating on the broad goal of strengthening the capacity of social scientists based within the national research system to conduct multidisciplinary, problem-solving research.

In 1987 researchers proceeded with a study of the policy and institutional constraints on more rapid adoption of improved wheat varieties and with research on maize-based farming systems in northern Pakistan (see page 46). Preliminary studies of higher altitude maize-based farming systems indicate that they require improved technologies that differ significantly from those recommended for the valley and plains.

Economics

Project:	**Haiti Economics Program, Phase II**
Donor:	Canadian International Development Agency (CIDA)
Pledge:	CA$ 788,395 (US$564,000 est.)
Duration:	January 1985 to December 1988
Financial Summary	Expenses (US$): Previous years $263,000 1987 $129,000 Total to date $392,000 Balance available $172,000

Objectives—The primary aim of this project is to assist Haitian researchers in the development and diffusion of improved technologies 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 Center staff working for the Central America and Caribbean Regional Maize Program, a core-restricted project funded by the Swiss Development Corporation.

Activities in 1987—One of the most important means of accomplishing the project's objectives is through on-farm research (OFR). Data generated from OFR in Les Cayes District resulted in changes in the local policy for providing fertilizer to farmers. At the request of the national program, in 1987 the project began work in a new area, Petit Goave, where a more complicated maize-based farming system on steep, erodable hillsides is being investigated.

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 $ 691,000 1987 $1,037,000 Total to date $1,728,000 Balance available $3,272,000

Objectives—This project is designed to provide assistance in conducting on-farm research (OFR) to a number of national agricultural research and extension institutions throughout the region. The total number of Economics Program staff in the project has been brought up to four: a new project staff member has been posted to Addis Ababa, two others reside in Nairobi and Lilongwe, and one in Harare.

Activities in 1987—Many countries in the region are now actively pursuing OFR. The greater number and distribution of CIMMYT economists permits them to offer more support to OFR in national programs through training courses, workshops, and consultation aimed at strengthening OFR capacities. Call system courses on basic OFR procedures were completed in 1987 in Ethiopia, Kenya, Zimbabwe, and Malawi, and numerous workshops were offered on the economic analysis of OFR results, among other topics. Training by project staff increasingly focuses on the methods and links between planning on-farm trials and the analysis of the resulting data. Staff spent a significant part of their time travelling to sites throughout eastern and southern Africa to participate in the planning and evaluation of on-farm trials.

The development of OFR programs places heavier demands on researchers and administrators to coordinate and integrate their work with other parts of national agricultural programs. To assist in those efforts, a senior research/extension administrators' workshop was offered in Lilongwe. Representatives of several countries and international agricultural research centers reviewed OFR projects in the region and discussed the support systems necessary to the success of OFR.

Information Services

Project:	**Information Service for Wheat and Other Small Grains**
Donor:	International Development Research Centre (IDRC), Canada
Pledge:	CA$371,250 US$284,000
Duration:	June 1984 to December 1987
Financial Summary	Expenses (US$): Previous years $156,000 1987 $128,000 Total to date $284,000 Balance available $- 0 -

Objectives—The purpose of this project is to provide information and documentation services for researchers working on wheat and other small grains.

Activities in 1987—The Scientific Information Unit (SIU) supported by the grant boosted its services markedly this year: some 400 database searches were done (a 100% increase over 1986), and close to 4000 documents were requested (an increase of 150%). In addition, the SIU provided 600 subscriptions for *Wheat, Barley, and Triticale Abstracts* (which CIMMYT copublishes with CAB International), 700 for the *Wheat, Barley, and Triticale Bibliography* (obtained from the International Information System for the Agricultural Sciences and Technology, AGRIS, which is coordinated by the Food and Agriculture Organization), and 650 of the *CIMMYT Scientific Information Bulletin*. The unit also conducted a survey in 1987 to measure the usefulness and targetting of its activities; respondents indicated a need for more specialized services.

Keeping pace with the growing demand for services, and for greater specialization within them (using essentially the same amount of resources), has required that the SIU take various steps to improve the efficiency and cost-effectiveness of its activities. The major one in 1987 was to acquire BASIS software, which has applications to integrated library management (on-line cataloging, control of serials, and circulation control). An important advantage of the software is that it will permit the unit to offer a new service, selective dissemination of information (SDI), in which clients will receive portions of the AGRIS bibliography selected specifically for them based on user profiles and keywords. That innovation makes it possible to serve more clients with no increase in expenditures.

Two other activities aimed at increasing efficiency were extensive training for staff (in the use of BASIS and other software, for example) and participation in information networking activities with other CGIAR centers. The purpose of the latter is to encourage collaboration among centers (in deciding which ones will maintain certain publications on microfiche, for example) and thus limit duplication and waste of resources.

Edith Hesse de Polanco (left), Head of the SIU, regularly assists trainees visiting scientists, and staff with special information requests.

Financial Statement

CIMMYT welcomed two new donors in 1987: the government of Finland provided unrestricted funds in support of our core program, and the government of Belgium donated extra-core funds for cooperative research on bacterial diseases of wheat. That brings to 13 the number of new donors to the Center's budget since 1980. The two new contributions, combined with the weakness of the US dollar in the world markets, boosted core revenues in 1987 by 10% over 1986 figures. Extra-core revenues, on the other hand, returned to more normal levels after reaching a peak in 1986, when we completed the Norman E. Borlaug Training,. Conference, and Information Center with extra-core funds from the Japan Shipbuilding Industry Foundation and Government of Japan.

Inflation and exchange rates continued to play an important role in CIMMYT management, determining annual revenues, wage adjustments, and major expenses for renovation and maintenance of the physical plant. Generally, the continued weakness of the dollar resulted in higher dollar revenues from donations denominated in other currencies. In a reversal of trends, annual inflation in Mexico outpaced the devaluation of the peso against the dollar, bringing about higher peso expenditures. They were offset, however, by higher core-unrestricted revenues.

The externally audited financial statement presented in the following pages shows the Center's financial condition at year end and the effects of financial flows during the year. Total assets increased over their 1986 level, a change reflected in cash and short-term deposits and in property, plant, and equipment. In view of the continuing importance of investment in the last three items, the Center formed a standing committee during 1987 to assess and manage medium- and long-term capital and maintenance needs.

Interest on short-term investments declined markedly, continuing a trend that was evident last year. An additional complicating factor is that most of CIMMYT's funds are now received during the latter half of the year, making cash management more difficult. We took one step toward solving our cash-flow problems in 1987 by increasing operating funds for the first time since 1981 and will continue to work with donors to identify other solutions.

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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, 1987 and 1986, 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)

	Note [a]	Year ended December 31 1987	1986
Assets			
Cash and short-term deposits	2	3,942	2,388
Accounts receivable			
Donors	6	1,232	1,570
Others	6	1,134	721
Inventories	2	63	95
Property, plant, and equipment	2	20,193	19,300
Total assets		**26,564**	**24,074**
Liabilities			
Accounts payable and other liabilities		829	1,204
Accrued benefits	2	467	377
Payments in advance from donors	6	4,028	2,194
Total liabilities		**5,324**	**3,775**
Fund balances			
Property, plant, and equipment	2,4	20,193	19,300
Capital development	4	400	400
Operating	4	2,765	2,415
Auxiliary services	4	364	138
Cumulative translation effect	3	(2,482)	(1,954)
Subtotal		1,047	999
Total fund balances		**21,240**	**20,299**
Total liabilities and fund balances		**26,564**	**24,074**

[a] The notes numbered 1 to 6 on pages 67-70 form an integral part of these financial statements.

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 1987	1986[b]
Revenue	5		
Grants		28,594	27,643
Sale of crops		36	47
Interest on short-term investments		108	196
Auxiliary services		761	734
Other income		1	1
Total revenue		**29,500**	**28,621**
Operating expenses	5		
Research programs		17,081	18,408
Conferences and training		5,460	3,921
Information services		888	697
General administration		1,895	1,834
Plant operations		1,395	1,306
Capital acquisitions		1,465	1,241
Auxiliary services		522	755
Accrual benefits		218	80
Total operating expenses		**28,924**	**28,242**
Excess of revenue over operating expenses		576	379
Allocated as follows:			
Operating funds		350	
Capital development fund	4		400
Auxiliary services	4	226	(21)
Translation effect for the year	3	(528)	(269)
Net excess of revenue over expenses		48	110
Fund, opening balances		999	889
Closing fund balances as per statement of condition		1,047	999

[a] The notes numbered 1 to 6 on pages 67-70 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.

Operating activities

Currency: US dollars (000s)

	Note[a]	Year ended December 31 1987	1986
Cash receipts:			
Grants from donors	5	28,594	27,643
Other	5	906	2,347
Subtotal		29,500	29,990
Translation effect for the year	3	(528)	(269)
Capital development fund	4		400
Operating fund	4	350	
Subtotal		29,322	30,121
Cash disbursements:			
Salaries and allowances		13,484	12,460
Travel		2,170	2,116
Training, conferences, and publications		5,472	3,601
Field and laboratory		2,803	3,399
Office and vehicle		3,312	3,975
Others		1,140	1,818
Subtotal		28,381	27,369
Cash provided by operating activities		941	2,752
Other activities:			
Additions to property, plant, and equipment	2	(893)	(2,642)
Accounts receivable from others	6	(413)	23
Accrued benefits	2	90	132
Inventories	2	32	(7)
Payments in advance from donors	2,6	1,834	(2,315)
Accounts receivable from donors	2,6	338	(440)
Accounts payable and other liabilities		(375)	(802)
Cash used in other activities		613	(6,051)
Increase (decrease) in cash and short-term deposits		1,554	(3,299)
Cash and short-term deposits at beginning of year		2,388	5,687
Cash and short-term deposits at end of year		3,942	2,388

[a] The notes numbered 1 to 6 on pages 67-70 form an integral part of these financial statements.

Notes to the Financial Statements

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

December 31, 1987 and 1986
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 hyperinflationary, i.e., with a cumulative inflation rate for the three last years greater than 100% 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, was 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, that 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 $141,000 in 1987 ($135,000 in 1986), and CIMMYT has recorded a liability of $153,000 in 1987 ($119,000 in 1986). The charge to income for the year amounted to $50,000 in 1987 ($83,000 in 1986) 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 certain unutilized benefits, such as leave time, by staff. That amounted to $314,000 in 1987 ($258,000 in 1986).

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, 1987, CIMMYT had Mexican peso assets and liabilities amounting to Ps 577,776,000 (Ps 365,895,000 in 1986) and Ps 1,014,845,000 (Ps 397,097,000 in 1986), which were included in the statement of condition at their US dollar equivalents resulting from applying the year-end rate of Ps 2,200 per dollar.

In 1987 the value of the Mexican peso compared to the dollar fell from Ps 911 to Ps 2,200 to the dollar (Ps 448 to Ps 911 in 1986). This devaluation gave rise to a translation loss aggregating $528,000 ($269,000 in 1986). In accordance with FAS 52, where the firm is judged to be operating in a hyperinflationary environment and the dollar is judged to be the functional currency, the translation effect in each year is charged to current income.

At February 22, 1988, date of issuance of the Financial Statements, the brokerage houses' exchange rates with the US dollar were Ps 2,255 (buy) and Ps 2,315 (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 1987, that had reached $20,193,000. 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. In 1987, CIMMYT placed $350,000 in that fund. At the end of 1987, the Center had $2,765,000 in operating funds. The surplus from CIMMYT's auxiliary services, such as food and housing of $226,000, is also shown under fund balances. And lastly, the accumulated effect from the translation of Mexican pesos and other currencies is listed under fund balances and in 1987 amounted to $2,482,000.

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 1987 and 1986, this fee was generally 15%, though for some on-campus activities it was 25%.

iii) Sale of crops. CIMMYT operates four experiment stations in 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 1987 and 1986, their expenses were as follows:

	1987	**1986**
	(000s)	
Maize	6,201	6,981
Wheat	6,342	6,853
Economics	1,845	1,680
Experiment Stations	1,455	1,410
Laboratories	314	401
Data Processing	700	840
Others	224	243
Total	17,081	18,408

Note 6: Accounts Receivable and Payments in Advance
Donors: In 1987 and 1986, these were as follows:

Accounts receivable from donors	**1987**	**(000s)**	**1986**
Austria, Government of	250		
Canadian International Development Agency	108		229
Germany, The Federal Republic of	39		20
International Crops Research Institute for the Semi-Arid Tropics	28		9
International Institute of Tropical Agriculture	18		23
International Center for Agricultural Research for Dryland Areas			84
International Development Research Centre	101		56
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank			90
OPEC Fund for International Development			69
Switzerland, Government of			326
The Netherlands, Government of	112		73
United Nations Development Programme	482		207
United States Agency for International Development	75		331
Other donors	19		53
Subtotal: Accounts receivable from donors	**1,232**		**1,570**
Payments in advance from donors			
Australia, Government of	(20)		(60)
Belgium, Government of	(30)		
Canadian International Development Agency	(507)		(112)
Danish International Development Agency	(78)		(67)
France, Government of	(28)		
Germany, The Federal Republic of	(183)		(32)
International Development Research Centre			(19)
Italy, Government of	(420)		(937)
Japan, Government of	(1,200)		(600)
OPEC Fund for International Development	(15)		
Switzerland, Government of	(938)		(53)
The Ford Foundation	(212)		(112)
The Rockefeller Foundation	(51)		
United States Agency for International Development	(185)		(11)
United Nations Development Programme			(65)
World Bank			(15)
Other donors	(161)		(111)
Subtotal: Payments in advance from donors	**(4,028)**		**(2,194)**
Net status of donors' payments	(2,796)		(624)

Others: In 1987 and 1986, these were as follows:

Receivables (payments)

	1987	**1986**
	(000s)	
Loans to senior staff	172	208
Personal charges to employees	2	(22)
Official expenses advances	657	450
Employee credit union	(18)	(49)
Miscellaneous debtors	321	134
Total	1,134	721

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

Detailed Statement of Activity For the Period January 1 to December 31, 1987

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

Exhibit 1

Currency: US dollars (000s)

	Note	Core unrestricted	Core restricted	Extra core and cooperative	Auxiliary services	Total
Revenue	5					
Grants		17,692	5,758	5,144		28,594
Sale of crops		36				36
Interest on short-term investments		108				108
Auxiliary services					761	761
Other income		1				1
Total revenue		**17,837**	**5,758**	**5,144**	**761**	**29,500**
Expenses	5					
Research programs		10,761	3,430	2,890		17,081
Conferences and training		2,396	1,459	1,605		5,460
Information services		888				888
General administration		1,895				1,895
Plant operations		1,395				1,395
Capital acquisitions		1,290	120	42	13	1,465
Auxiliary services					522	522
Indirect costs		(1,356)	749	607		0
Seniority premiums—accrual leave		218				218
Total operating expenses		**17,487**	**5,758**	**5,144**	**535**	**28,924**
Excess of revenue over operating expenses Allocated as follows:		350			226	576
Operating fund	4	350				350
Auxiliary services	4				226	226
Translation effect for the year	3	(528)				(528)
Net (defect) excess of revenue over expenses		(178)			226	48

Sources of Income From Grants For the Period January 1 to December 31, 1987

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	611		40	651
Austria, Government of	250			250
•Belgium, Government of			127	127
Canadian International Development Agency	1,336		1,740	3,076
China, People's Republic of	50			50
Danish International Development Agency	496		32	528
European Economic Community		1,003		1,003
Finland, Government of	700			700
France, Government of		435		435
Germany, The Federal Republic of	550		208	758
India, Government of	99			99
Inter-American Development Bank	4,385			4,385
International Crops Research Institute for the Semi-Arid Tropics			300	300
International Development Research Centre			162	162
International Institute of Tropical Agriculture			65	65
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank			89	89
Ireland, Government of	105			105
Italy, Government of		370	147	517
Japan, Government of		1,363	12	1,375
Mexico, Government of	88			88
Norwegian Agency for International Development	153		58	211
OPEC Fund for International Development		82		82
Spain, Government of	115			115
Switzerland, Government of		497	346	843
The Ford Foundation	100			100
The Netherlands, Government of		256		256
The Philippines, Government of	27			27
The Rockefeller Foundation			49	49
The United Kingdom, Government of	1,177			1,177
The World Bank	2,200			2,200
United Nations Development Programme		1,752	3	1,755
United States Agency for International Development	5,250		1,680	6,930
Miscellaneous Training and Research Grants			86	86
Total income from grants	**17,692**	**5,758**	**5,144**	**28,594**

Core-Restricted Pledges and Expenses For the Period January 1 to December 31, 1987

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	Expenses: This year	Expenses: Total
Government of France					
Collaborative Research—Maize	01/01/87-12/31/87			206	206
Bread Wheat	01/01/87-12/31/87			61	61
Triticale	01/01/87-12/31/87			61	61
Economics	01/01/87-12/31/87			49	49
Agronomy	01/01/87-12/31/88			34	34
Plant protection	01/01/87-12/31/87			24	24
Total		**462[b]**	**N/A**	**435**	**435**
Government of Japan					
Wheat Disease Surveillance	01/01/87-12/31/87			393	393
Wheat and Maize Plant Protection	01/01/87-12/31/87			705	705
Wheat Southern Cone	01/01/87-12/31/87			265	265
		1,363[c]	**N/A**	**1,363**	**1,363**
OPEC Fund for International Development					
Maize West Africa, Phase IV	07/01/86-06/30/87	116	69	47	116
Maize West Africa, Phase V	07/01/87-06/30/88	100		35	35
Total		**216**	**69**	**82**	**151**
Government of Switzerland					
Central America and Caribbean—Maize	01/01/87-12/31/89	1,100		317	317
Central America and Caribbean—Economics	01/01/87-12/31/89	500		180	180
Total		**1,600**	**N/A**	**497**	**497**
Government of The Netherlands					
Economics	01/01/87-12/31/87	144		144	144
Computer Programmer	01/01/87-12/31/87	112		112	112
Total		**256**	**N/A**	**256**	**256**

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	1,827	1,058	2,885
Tropical Wheat	07/01/82-06/30/87	2,415	2,078	337	2,415
Development of Wheat Varieties for Marginal Areas	07/01/87-06/30/90	2,437		357	357
Total		**9,874**	**3,905**	**1,752**	**5,657**
European Economic Community					
Andean Regional Wheat and Maize	01/01/87-12/31/89	3,000[d]		1,003	1,003
Government of Italy					
Barley Yellow Dwarf Virus	01/01/87-12/31/87	370		370	370
Total core restricted			**3,974**	**5,758**	**9,732**

a For information purposes only.
b Equivalent to FF 2,600,000 and US$37,500.
c Equivalent to YEN 195,600,000.
d Equivalent to ECU 3,000,000.

N/A = Not applicable.

Extra-Core Pledges and Expenses For the Period January 1 to December 31, 1987

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

Exhibit 4

Currency: US dollar (000s)

	Grant period[a] (month/day/year)	Grant pledged[a]	Expenses: Prior years	Expenses: This year	Expenses: Total
United States Agency for International Development					
Pakistan Agricultural Research Council—Wheat, Maize, and Economics	10/01/84-09/30/87	4,185[b]	1,747	632	2,379
Africa On-Farm Research, Phase II	01/01/86-05/20/90	5,000	691	1,037	1,728
Agronomic Wheat Production	08/01/85-11/30/87	25	14	11	25
Total		**9,210**	**2,452**	**1,680**	**4,132**
United Nations Development Programme					
Turkey Wheat	12/31/83-03/31/86	380	391	(11)	380
Consultancy	07/09/87-08/09/88			14	14
Total		**380**	**391**	**3**	**394**
Canadian International Development Agency					
Triticale Research and Training	04/01/78-12/31/87	286[c]	278	6	284
Haiti—Economics	01/01/85-12/31/88	564[d]	263	129	392
East Africa Cereals Program	10/01/84-06/30/88	2,038[e]	995	669	1,664
Ghana Maize, Phase II	10/01/83-09/30/88	3,803[f]	2,245	615	2,860
Bangladesh—Wheat	04/01/82-03/31/88	3,744[g]	2,181	321	2,502
Total		**10,435**	**5,962**	**1,740**	**7,702**
Government of Switzerland					
Central America and Caribbean—Maize	01/01/87-12/31/89	714[h]		215	215
Central America and Caribbean—Economics	01/01/87-12/31/89	400		101	101
Economics Training	08/19/86-08/18/89	84	21	30	51
Total		**1,198**	**21**	**346**	**367**
Instituto Nacional de Investigación y Promoción Agropecuaria, Peru/World Bank					
Wheat	08/01/83-12/31/87	482	394	89	483

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 Federal Republic of Germany					
African Students Postgraduate Fellowships	01/09/87-01/09/88	120		1	1
Wheat International Agricultural Research	07/01/86-06/30/89	591	60	191	251
Enhancement of Disease Resistance in Quality Protein Maize	07/01/86-06/30/88	48	3	16	19
Total		**759**	**63**	**208**	**271**
Government of Belgium					
Wheat Bacterial Disease Project	01/01/87-12/31/89	414	N/A	127	127
Government of Italy					
Barley Yellow Dwarf Virus	01/11/84-10/31/89	1,185	618	147	765
Government of Japan					
Fellowships Program	09/01/86-12/31/88	606		10	10
Cafeteria, Building	09/01/87-12/31/88	306		2	2
Total		**912[i]**	**N/A**	**12**	**12**
Norwegian Agency for International Development					
Predoctoral Fellowship	01/01/87-12/31/87	58[j]	N/A	58	58
International Development Research Centre					
Bibliographic Service on Wheat and Small Grains	01/01/84-12/31/87	50[k]	16	34	50
Information Services on Wheat and Small Grains	06/29/84-06/30/87	284[l]	156	128	284
Total		**334**	**172**	**162**	**334**

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

	Grant period[a] (month/day/year)	Grant pledged[a]	Expenses		
			Prior years	This year	Total
Biotechnology Consortium					
Government of Australia	01/09/84-01/09/88	149[m]	89	40	129
Danish International Development Agency					
DPS Associate Scientist	09/01/86-08/30/89	137	16	32	48
International Institute of Tropical Agriculture					
SAFGRAD	01/01/87-12/31/87	N/A	N/A	65	65
The Rockefeller Foundation					
Sub-Saharan Africa	05/01/87-12/31/87	100	N/A	49	49
Miscellaneous Training Grants	n	N/A	N/A	86	86
Cooperative Projects					
ICRISAT-Sorghum Project	01/01/81-12/31/87	1,695	1,153	300	1,453
Total Extra Core			**11,331**	**5,144**	**16,475**

a For information purposes only.
b Includes RPs 38,529,064 equivalent to US$2,310,873.
c Equivalent to CA 338,944.
d Equivalent to CA 778,395.
e Equivalent to CA 2,753,000.
f Equivalent to CA 4,754,300.
g Equivalent to CA 4,680,000.
h Includes US$14,424 of interest earned.
i Equivalent to YEN 136,164,000 and includes US$12,000 of interest earned.
j Equivalent to NOK 400,000.
k Equivalent to CA 67,105.
l Equivalent to CA 371,050.
m Equivalent to AD 190,000.
n Grant period not applicable; donor pays tuition for each trainee sponsored.

N/A = Not applicable.

Appendix: Distribution of International Trials

Distribution of Maize Program international trials, 1987

	Progeny trials	Variety trials
Africa	**12**	**286**
Algeria	-	1
Angola	-	1
Benin	-	4
Burkina Faso	-	10
Cameroon	1	-
Cape Verde	-	2
Chad	-	6
Congo	-	8
Côte d'Ivoire	2	18
Egypt	1	6
Ethiopia	-	23
Ghana	1	20
Guinea	-	4
Kenya	2	36
Liberia	-	2
Madagascar	-	8
Malawi	2	13
Mauritania	-	4
Morocco	-	4
Reunion	-	5
Rwanda	-	14
Senegal	-	29
Sierra Leone	-	18
Somalia	-	16
South Africa	-	5
Tanzania	2	5
Togo	-	5
Uganda	-	6
Zaire	1	13
Asia	**19**	**247**
Afghanistan	-	7
Bangladesh	-	38
Bhutan	-	3
Burma	-	8
China	2	22
India	6	9
Indonesia	1	11
Korea, South	-	1
Laos	-	4
Nepal	1	9
Pakistan	2	21
The Philippines	1	28
Sri Lanka	-	4
Taiwan	-	25
Thailand	4	32
Vietnam	2	25
Europe	**-**	**5**
France	-	1
Greece	-	2
Hungary	-	1
Spain	-	1
Latin America and the Caribbean	**50**	**263**
Argentina	-	7
Belize	-	4
Bolivia	-	10
Brazil	6	19
Chile	-	2
Colombia	-	32
Costa Rica	3	9
The Dominican Republic	2	2
Ecuador	2	14
El Salvador	2	2
Guatemala	2	-
Honduras	2	2
Jamaica	-	3
Mexico	26	79
Nicaragua	-	4
Panama	-	18
Paraguay	2	6
Peru	3	19
Saint Vincent	-	18
Surinam	-	2
Uruguay	-	4
Venezuela	-	7
Middle East	**-**	**24**
Iraq	-	2
Iran	-	4
Jordan	-	2
Kuwait	-	1
Qatar	-	1
Saudi Arabia	-	2
Syria	-	2
Turkey	-	10
North America	**-**	**1**
USA	-	1
Total trials	**81**	**826**
Total countries	**26**	**78**

Distribution of Wheat Program international nurseries, 1987

	Bread wheat	Durum wheat	Triticale	Barley	Germplasm development	Special nurseries[a]
Africa	**264**	**90**	**61**	**56**	**41**	**43**
Angola	4	-	1	-	-	-
Cameroon	23	5	4	3	1	4
Congo	7	-	-	-	-	-
Egypt	0	12	6	5	11	3
Ethiopia	10	7	-	2	-	5
Kenya	14	5	3	6	4	7
Libya	9	7	1	2	-	3
Malawi	4	-	4	2	3	7
Morocco	6	10	-	1	3	8
Mozambique	18	9	7	4	4	-
Nigeria	13	-	-	2	-	-
Rwanda	14	-	3	2	-	-
Sierra Leone	6	2	1	2	2	-
Somalia	2	-	-	-	-	-
South Africa	38	10	9	8	9	6
Sudan	12	-	2	-	1	1
Tanzania	14	-	4	6	1	1
Tunisia	9	10	5	4	1	3
Zaire	6	-	-	-	-	-
Zambia	11	-	4	-	-	1
Zimbabwe	14	2	3	7	1	1
Asia	**313**	**45**	**54**	**55**	**57**	**50**
Afghanistan		-	3	-	-	1
Bangladesh	23	1	1	1	1	-
Bhutan	5	-	-	1	1	-
Burma	9	-	-	1	1	-
China	117	16	18	28	27	21
India	21	13	8	-	4	7
Indonesia	15	-	-	-	1	1
Japan	2	-	-	-	1	1
Korea, South	6	-	4	3	2	1
Nepal	15	-	-	2	1	1
Pakistan	48	10	8	14	11	14
The Philippines	24	1	3	2	3	2
Thailand	25	4	9	4	6	2
Vietnam	3	-	-	-	-	2
Europe	**218**	**110**	**102**	**69**	**66**	**40**
Albania	15	6	4	4	4	4
Austria	-	4	2	-	1	-
Belgium	6	-	3	3	2	-
Bulgaria	5	6	4	-	5	1
Czechoslovakia	4	-	1	3	5	-
England	8	1	3	2	2	-
Finland	-	-	3	1	-	-
France	22	11	8	7	3	-
German, East	3	1	1	2	3	5
German, West	6	12	9	3	2	2
Greece	14	7	6	5	3	5
Hungary	-	2	3	1	2	

Continued next page

Wheat nurseries, continued

	Bread wheat	Durum wheat	Triticale	Barley	Germplasm development	Special nurseries[a]
Ireland	5	-	-	3	1	
Italy	9	16	5	4	8	6
The Netherlands	6	2	3	-	1	-
Norway	4	-	2	2	-	-
Poland	3	1	8	4	3	-
Portugal	11	6	6	3	4	2
Romania	4	-	3	-	-	1
Spain	58	25	16	18	8	1
Sweden	4	-	3	-	-	11
Switzerland	5	1	3	1	1	1
USSR	10	9	1	-	2	1
Yugoslavia	16	-	5	3	5	1
Latin America	**357**	**118**	**89**	**43**	**68**	**55**
Argentina	49	21	9	3	11	2
Bolivia	19	19	5	2	3	-
Brazil	63	2	21	6	20	5
Chile	42	27	12	-	12	13
Colombia	25	2	-	6	5	5
Ecuador	-	6	2	-	-	9
Guatemala	22	-	-	4	-	-
Mexico	56	24	24	12	7	11
Paraguay	34	1	6	1	5	3
Peru	31	12	9	5	5	7
Uruguay	9	-	-	2	-	-
Venezuela	7	4	1	2	-	-
Middle East	**128**	**71**	**34**	**39**	**32**	**31**
Cyprus	2	1	1	2	-	-
Iran	12	6	2	8	1	2
Iraq	2	1	1	-	-	-
Israel	18	6	2	-	8	3
Jordan	16	14	3	6	1	3
Lebanon	1	3	-	3	-	-
Qatar	4	-	3	2	-	-
Syria	31	16	11	8	10	14
Turkey	37	24	8	8	11	9
Yemen Arab Republic	5	-	3	2	1	-
North America	**9**	**3**	**5**	**14**	**2**	**18**
Canada	9	1	3	7	1	6
USA	-	2	2	7	1	12
Oceania	**21**	**7**	**8**	**1**	**6**	**6**
Australia	14	1	4	1	6	1
New Zealand	7	6	4	1	-	5
Total nurseries	**1310**	**444**	**353**	**276**	**272**	**243**
Total countries	**79**	**56**	**69**	**63**	**59**	**50**

[a] Special nurseries include International Disease Trap Nurseries, the Karnal Bunt Screening Nursery, and four Barley Yellow Dwarf Virus Nurseries.

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Conference and Seminar Presentations

A number of papers in addition to those listed below were presented by staff during 1987 and will be available in proceedings to be published by CIMMYT in 1988.

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