DISCUSSION DRAFT

CIMMYT PLANNING REPORT

A LOOK AHEAD

1980-86

FEBRUARY 15, 1980

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO

INTERNATIONAL MAIZE AND WHEAT IMPROVEMENT CENTER

México

DISCUSSION DRAFT

CIMMYT PLANNING REPORT

A LOOK AHEAD

1980-86

FEBRUARY 15, 1980

TABLE OF CONTENTS

PREFACE

The evolution of CIMMYT's programs has constantly been shaped by the accumulated experience of its staff and by continuing communication with agriculturists and planners in developing countries and international development assistance agencies. This process of review and planning has been synthesized in three earlier planning reports. The first covered the years 1966-69, and the second, the period from 1971 to 1975. Finally, two international conferences held at CIMMYT in 1973-74 helped shape general program directions in maize, wheat, barley and triticale improvement during the 1970's. This new report, the latest in CIMMYT's efforts to assess and plan its future, represents the thinking of staff and trustees. In its final form, it will also have gone through an intensive review by trustees, donors, staff and informed critics.

The preparation of this planning document has been a long and somewhat arduous process. It began nearly a year ago with discussions between CIMMYT staff and the members of the CIMMYT Trustees Program Committee. During the past year, Program Committee meetings focused on these planning issues. CIMMYT's internal review in 1979 also was devoted to this purpose. Staff have reviewed numerous publications related to world trends in population growth, food production, land resources, energy issues, etc. The year 2000 was taken as a basic reference point to focus CIMMYT's view of the circumstances of mankind toward which we should devote our activities over the next few years. The prognostications concerning absolute population levels, changing trends in food production, and the land and water resource base available for food production vary considerably. But all estimations point in the same direction: world population by the 2000 will be substantially larger, the land available for food production limited, and the need for expanded production of staple foods more critical if human welfare is to be improved, or indeed, even maintained at 1980 levels.

The pace of population growth and the existing plight of all too many of the world's people dictate the dimensions of the challenges ahead in feeding the world. Massive levels of capital investment are needed to improve the productivity and dependability of the land and water resource base used for food production. Even under the best circumstances, many of these investments will have only a marginal impact on food production in the next 10—or perhaps even 20—years. Given the continued rate of population growth then, dependable additional production must be achieved largely from land currently under cultivation.

In the process of reviewing the world food situation and its implications on future CIMMYT activities, the staff prepared over 400 pages of background materials concerning the current status of CIMMYT programs and likely future directions of research and production activities. CIMMYT's editorial staff, in summarizing the major ideas developed during this program review and planning process, aimed at producing a short document which presents the program highlights in non-technical language for an informed agricultural development audience.

The conditions faced by resource poor farmers have always featured heavily in the planning and execution of CIMMYT's research and production programs. Recognizing that in most environments, the genetic potential of CIMMYT materials far exceeds the production levels achieved, CIMMYT plans to spend relatively more of its available resources on problems related to improved crop management (agronomy) and yield dependability (largely through genetic resistance or tolerance).

The location-specific nature of these problems dictates that most of CIMMYT's further staff expansions will occur in regional programs where staff are much closer to the problems and can relate more closely on a sustained basis with scientists in national programs.

The eight people who make up CIMMYT's current directing staff collectively have spent 131 years living in the developing world and working on problems related to agriculture. To summarize their collective perceptions is not an easy task. It is often difficult for the non-scientist to comprehend the complexity and long-term nature of biological processes. Based on years of experience and a great deal of data a scientist must decide which crosses to make between desirable plant types, with the full knowledge that even if a particular cross proves to be the one among thousands which will survive the selection process, a decade will elapse before it becomes a commercial variety used in any appreciable amount on farmers' fields. Further, since many pests and pathogens constantly change in their ability to attack newly developed varieties, the usefulness of any particular variety may be short-lived. Thus, unless the scientific program is constantly progressing, it faces a tendency to revert to former, lower levels of productivity. Unless policy makers in developing countries and representatives of donor agencies funding research organizations understand these complexities, sustained progress cannot be made. The lack of communication between agriculturists and policy makers remains one of the most vexing problems in agricultural research and production.

In CIMMYT's view, there seldom has been a time in recent history when predictions of future developments are more difficult to make than at present. The rapidly increasing cost of fuel and its related price increases have left many irrigation pumps idle, field vehicles used by researchers and extension workers parked at headquarters, and personnel idle at their desks. In many countries, funds available for agricultural development are woefully inadequate in comparison to the job which lies ahead. The rate of inflation currently being experienced by many countries makes it difficult to mobilize funds, even to maintain current activities.

Despite the difficulties facing developing countries, CIMMYT staff is convinced that, from a biological view point, it is possible to expand agricultural food production over the next 20 years at a rate that will equal or slightly exceed the rate of aggregate population growth. Achieving this increase and distributing it more equitably, however, will require political stability, the determination of national governments to increase investments in their agricultural sector–including research and extension–and the sharing of new knowledge and genetic material among the community of nations. While there will be changing comparative bureacritic advantages and different tasks to perform for the many organizations concerned with agricultural development, CIMMYT believes the network of agricultural research institutes has a vital role to play in the years ahead. The ability of CIMMYT to continue to effectively respond to its mandate will depend substantially on a continuation, in real terms, of the generous support which donor organizations have provided in the past, and a recognition that the flexibility of the Center must be maintained to meet the ever-changing challenges of the years ahead.

Robert D. Havener
Director General

CHAPTER ONE

EVOLUTION OF THE INSTITUTE

INTRODUCTION

CIMMYT in 1980 is a many faceted institution concentrating on the problems of maize and wheat production in developing countries. Its multidisciplined staff, while headquartered in Mexico, works around the world where maize or wheat is important to developing countries.

CIMMYT's primary research thrust is to develop, in close collaboration with scientists from developing countries, new varieties of maize, wheat, barley and triticale that are capable of high and dependable yields across many production environments. Hallmarks of the Center's programs are the commitment to multidisciplinary, pragmatic research and to the promotion of strong national research and production programs.

Against a background of what might transpire over the next two decades, this report charts general program directions and plans for the period 1981-1986. It starts with a review of the Center's organizational evolution, offers a brief summary of its contribution to world agriculture, turns to the food production challenges ahead, and then describes current CIMMYT thinking on how best to support and complement developing country agricultural programs during the planning period. It closes with a synthesis of planned changes in emphasis and staffing to 1986.

ORGANIZATIONAL PHASES

The Center's history can be seen in three phases. The first opens in 1943 with the initiation of a pioneering project by Mexico's Department of Agriculture and the Rockefeller Foundation (RF). Its goal was to improve the productivity of agriculture as a part of Mexico's overall strategy to promote greater domestic prosperity. For the better part of two decades, RF staff worked with Mexican colleagues on the problems of Mexico's farmers.

During this first phase certain principles evolved which still guide CIMMYT's activities. Cooperation was largely with public sector institutions with free exchange of information. Research efforts were guided by pragmatic considerations and aimed at the immediate production problems of farmers. Training of national researchers was a primary program activity.

The second phase, 1961-66, was transitional to the creation of CIMMYT. In 1961 Mexico established the National Institute for Agricultural Investigations (INIA) and assigned it the responsibility of carrying on the research needed to serve Mexican agriculture. With the creation of INIA, the RF staff based in Mexico began to shift ever more attention to issues outside of Mexico, increasing their concern for activities in other parts of the globe, especially in Latin America and South Asia. Typical of this new orientation was the increasing amount of germ plasm contributed to international nurseries. The first of these, a USDA sponsored Stem Rust Nursery, was distributed in the early 1950's with important contributions from the Mexican program.

By 1960 the Mexican program was itself sponsoring such nurseries beginning with the Inter-American Spring Wheat Nursery, followed in 1962 by the Near East-American Spring Wheat Yield Nursery and in 1964 by the International Spring Wheat Yield Nursery. Meanwhile, researchers in maize were responding to requests for germ plasm, mainly from the national programs of Latin America.

Again this experience contributed research principles which CIMMYT continues to follow. Multilocation testing clearly demonstrated its utility in identifying and developing cultivars with broad adaptation and good yielding ability. Second, this sharing of germ plasm brought new genetic variability to national programs, accelerating crop improvement and ushering in a new era in plant breeding. Finally, the benefits of a multi-national network of crop improvement specialists became evident.

The experiences of the Mexican program provided some of the guidelines followed in establishing IRRI in 1961. Later, these guidelines and those from IRRI's accumulating experience oriented CIMMYT's formal initiation in 1966. This date marks the institution's third phase, characterized by a full commitment to international activities and responsible to an independent, international Board of Trustees.

CIMMYT launched its third phase with a clear international focus, and with financial support mainly provided by the Ford and Rockefeller Foundations. It soon became apparent that additional financing would be required to meet the growing demands for international agricultural research. Increasing concern for agriculture in developing countries, coupled with the impressive early successes of CIMMYT and IRRI and the emerging constraints on funding, led to discussions about an expanded system for supporting such research.

These discussions were held between 1969 and 1971 and gave rise to the expanded system of which CIMMYT is now a part. Called the Consultative Group for International Agricultural Research, the system provides a mechanism through which donors can support research targeted on the needs of developing countries. The CGIAR was established in 1971 under the joint auspices of FAO, UNDP, and the World Bank. Its organizing principles are to build bridges of voluntary association between researchers and donors, while respecting the scientific requirements of the first and the political accountability of the second. The Group went on to establish a Technical Advisory Committee, made up of distinguished agricultural scientists and research administrators, to advise on global priorities for the international research system.

CIMMYT recognizes its privileged place as a member of the international agricultural research community and is proud of its part in the evolution of the CGIAR system. Its plans for the future, described in the chapters which follow, give evidence of its role in the international effort to continue improvements in national agricultural production systems.

CHAPTER TWO

CIMMYT'S RECENT PAST

RESPONSE TO A MANDATE

CIMMYT's mandate calls for it to complement and support the research efforts of those developing countries concerned with the production of maize and wheat. The Center's best known contributions are in wheat. Over 30 million hectares of wheat in developing countries are now planted to varieties based on CIMMYT's germ plasm. These varieties have brought remarkable production increases in many developing countries. [1/] While efforts in maize have not yet achieved such dramatic successes, there is mounting evidence of significant CIMMYT contributions to varietal improvement and husbandry throughout the developing world.

The center provides five kinds of services to national programs: improved germ plasm; training for staff; procedures for conducting research; consultation on the organization of relevant research and production programs; and information to national programs and others. While CIMMYT features these activities, it recognizes that they are not ends, but means to assist national programs to forge suitable technologies for farmers. Therefore, each activity described briefly in the following pages must eventually be judged by its consequences for production on farmers' fields. (For additional program detail, see **CIMMYT Review 1979.**)

GERM PLASM

CIMMYT's dominant activities are in crop improvement. While there are some differences in procedures followed in maize, an open pollinated crop, and wheat, a self pollinated crop, both programs adhere to the principle of large-scale multilocational testing and selection in which national collaborators play a partnership role. Materials exhibiting superior characteristics at many testing locations are used in future improvement activities, thus reinforcing the useful traits in germ plasm distributed in succeeding testing cycles.

In maize, the international crop improvement effort focuses on population improvement. The system, which draws on methodological research carried out by CIMMYT in its earlier years, begins with progenies selected from populations constituted to fit major production areas on the basis of grain type, maturity characteristics, and agro-climatic circumstances. These progenies are themselves improved in Mexico and then sent upon request to appropriate collaborators for evaluation. Their selections are recombined to form experimental varieties tested today in 85 countries. After additional testing in appropriate environments, varieties can be identified, named, and released by national programs, or the resulting materials can be used as elements in national crop improvement programs.

In the small grains improvement programs, 38 different types of nurseries of bread wheat, durums, triticales, and barley were distributed in

1980 to national collaborators in more than 115 countries. These nurseries include materials for crossing and selecting—both early and advanced generations—cultivars already released as commercial varieties in various countries, screening nurseries, and yield nurseries. All of the 38 nurseries have been designed to group materials for assessment in relevant environments and, at the same time, to introduce new germ plasm to national programs.

All international testing programs at CIMMYT have been structured in such a way that every national program— well established or just beginning— is able to utilize germ plasm of potential benefit to their research efforts. Furthermore, the materials tested are grouped in such a way as to be of maximum utility to national programs. For CIMMYT, the extensive observations and measurements made by collaborators in the international testing network reinforce Center efforts to develop widely-adapted materials of potential benefit to a wide range of production environments. In addition to serving as the hub for international germ plasm exchange, CIMMYT also supports special collaborative research efforts with selected national programs to develop materials resistant to specific diseases, insects or to problem soils.

PROGRAMS FOR STAFF DEVELOPMENT

The continual improvement in the human capabilities of those involved in food production is a critical factor in determining future progress in agricultural development. CIMMYT contributes to the development of human resources by expanding the educational and training opportunities open to agricultural scientists in national research and production programs. Such efforts have taken many forms and combinations.

A variety of CIMMYT in-service training programs in crop improvement, agronomy, experiment station management, laboratory sciences and techniques, and economics have been offered to more than a thousand young agriculturists over the past twelve years. Emphasis in all such programs, which usually last a full crop cycle, is on developing practical research methods applicable to actual field research conditions.

CIMMYT also receives significant numbers of visiting scientists at headquarters each year. These scientists are senior workers who spend from a few weeks to one year in CIMMYT's on-going research and training activities. Workshops, seminars, publications, visiting scientist travel fellowships to other national programs, and consultation with CIMMYT staff further help to strengthen the scientific manpower available to national programs.

On a limited basis CIMMYT also cooperates in the training of scientists from national programs through the support of graduate and postgraduate training. Over one hundred young scientists interested in careers in agricultural research have benefited from such fellowship programs.

Finally, CIMMYT's regional programs and its staff deputed to national programs also engage in training activities. These range from offering short-courses to identifying candidates for other kinds of training.

PROCEDURES FOR CONDUCTING RESEARCH

The years of research conducted by CIMMYT in collaboration with agricultural scientists from national programs have resulted in the development of path-breaking research procedures utilized today by many crop improvement and production programs around the world. These procedures, all based on scientifically sound practices, have emerged from CIMMYT's own efforts to make its field techniques more efficient. Once established as sound, they are available to national programs to expedite their own work.

In maize, the multi-trait population improvement procedures, combined with the system of multilocational testing are effective procedures for developing high yielding, widely-adapted, open-pollinated varieties. Insect infestation techniques fashioned by CIMMYT have accelerated the development of maize material with greater resistance to insects. CIMMYT scientists also have formulated new procedures to develop normal looking, normal tasting, maize materials with substantially higher levels of nutritional quality.

In small grains breeding, the assessment of large numbers of experimental lines under very diverse climatic conditions has proven to be a successful strategy in identifying broadly adapted cultivars capable of high yields over a wide range of production environments. This strategy led to the wheat varieties which have had such an enormous impact on wheat production around the world over the past twenty years.

CIMMYT scientists are working on organizational procedures to better orient agricultural research efforts toward the most pressing problems faced by farmers. These practical procedures offer an efficient way of developing more appropriate production recommendations. They also provide a mechanism for harmonizing the efforts of farmers, agricultural scientists, extension workers, and policy makers in their attempts to improve rural incomes and nutrition.

CONSULTATION

With CIMMYT's long years of research and production experience under varying conditions, national programs often call for counsel on the organization of research on maize and wheat and on ways to reduce the constraints limiting production. The themes treated include methods and strategies for effective crops research, organizing and supporting crops research, the relationship between research and the diffusion of technologies, training requirements, and counsel on policy issues related to production problems. One of the distinguishing concepts emphasized by CIMMYT is the integration of research, from the earliest stages under experimental conditions to verification of recommendations under appropriate circumstances.

INFORMATION

Each year, CIMMYT prepares a number of new publications on its work for distribution to colleagues and other interested parties. CIMMYT also distributes selected materials of special interest published by others to its staff and colleagues. Some of these publications deal directly with germ plasm improvement, and others with training, procedures or policy-related issues. Such information is a valuable tool in the development and diffusion of improved technology.

SUPPORTING SERVICES

In order to provide effective service to national programs CIMMYT has developed a range of support services in Mexico and elsewhere. These services are of two broad types—one concentrated on research support and the other on administrative support.

Research support includes the activities of three principal units: experiment stations, laboratories, and data processing services. Those in the experiment stations are responsible for general station upkeep of facilities and equipment, land preparation, irrigation and other husbandry activities on research plots.

Laboratory staff analyze the protein, baking and industrial qualities of thousands of cereal samples, along with soil and water analyses for the experiment stations and on-farm production training programs.

The data processing group analyzes the data from the thousands of international trials grown each year by national cooperators in more than 130 countries. Additional data processing and statistical counselling is also provided to CIMMYT staff in other research areas.

The administrative services run the gamut from housekeeping activities, to libraries, to purchasing and travel, to financial control, and to the Center's central direction. A wide range of skills and talents are needed to supply such services.

It is evident that CIMMYT's continuing contribution in international research rests squarely on the quality of its support services. With more than a decade of experience CIMMYT has a clear sense of what is required and a staff which ensures its delivery. (See **CIMMYT Review 1979** for details.)

REFERENCES CITED

1. "Development and Spread of High-Yielding Varieties of Wheat and Rice in Less--Developed Nations," Dana G. Dalrymple, 1978.

CHAPTER THREE

FEEDING THE WORLD—THE CHALLENGES AHEAD

MAN AND CEREALS

On a global basis, mankind depends on the land for 98 per cent of its food supply. This is not expected to appreciably change in the remainder of this century. In terms of human well-being, the most important food products are cereals, the grain crops that occupy some 70 per cent of the world's cropland area. Together, wheat, rice, maize, barley and the other cereals supply well over half of the food energy when consumed directly and a sizable part of the remainder when consumed indirectly in the form of livestock products. These proportions might even increase in the future if higher yielding cereals replace lower yielding pulses. Between 1961 and 1978, world cereal production increased 70 per cent and production per capita climbed by over 30 per cent but much of this increase occurred in developed countries.[1/]

With every succeeding year, each additional improvement in per capita world cereal production—an important measure of improving human welfare—becomes a more difficult task to achieve. The economics of agricultural development, with its strong energy implications, will continue to require growing investments to develop the needed infrastructure capable of sustaining growth in cereal production.

SOURCES OF NEW PRODUCTION

A growing world population and increasing per capita incomes continue to dictate future global demands for food stuffs. One aspect of this increasing demand is that, more and more, it will emerge from urban areas. While roughly 30 per cent of the population of developing countries was in urban areas in 1979, by the year 2000 roughly half of the much larger population will be urban.[2/] This population will depend exclusively on commercial agriculture for its food supply.

At the same time, global estimates of the numbers of people suffering from chronic protein-calorie deficiencies are large and apparently growing. Seen geographically, the world's most urgent food problems are in Asia and, to a lesser degree, in sub-Sahara Africa.[3/] Most of the world's under-nourished are small children, with pregnant and nursing mothers the second most vulnerable group. These two groups face a continuing nutritional threat because of cultural traditions that discriminate against small children and females of all ages in the allocation of food supplies.

On a world scale, the required production increases for the next twenty years can come from three sources: bringing new lands into production, increasing cropping intensities, and yield increases. CIMMYT does not hold great optimism for significant additions to cropland during the final quarter of the century. Certainly some new land will be brought into cereal production, possibly in the Amazon basin and Argentina as well as in sub-Sahara Africa. In addition, through irrigation—with its implications for cropping intensity and yield, new sources of production will become available, e.g.—the Gangetic plain, the Indus basin, the Mekong delta, and the Sudan. These sources of new productivity will require heavy investments and sufficient periods of political stability to mature.

Potential additions to the land base must be balanced against the losses in land area and quality being suffered year after year. According to a recent UN survey, at least 20 per cent of the world's cropland is losing top-soil or being otherwise degraded at a rate that will seriously undermine productivity over the long run.[4/] Irrigated areas, which account for a disproportionally large share of the world's food production, are facing increasingly critical problems. Although over half of the world's irrigated capacity, particularly in the developing countries, has been put in place over the past 25 years, waterlogging and salinity are already impairing these newly irrigated lands. Beyond that, there are continuing losses of cropland to non-farm uses. Unless careful attention is focused on these problems CIMMYT believes that during the next twenty years the world will face serious threats from cropland abandonment due to desertification, deforestation, severe erosion, waterlogging and salinization of irrigated land, and in some key producing areas—particularly in the developed countries—from the diversion of irrigation water to non-farm uses.

On balance, CIMMYT believes that it will be very difficult for the world to achieve significant net expansions in cropland area during the remainder of this century. The trends experienced during 1953-1975, when expansions in cultivated area fell increasingly behind rates of population growth, will continue.[5/] A recent FAO study, claims that almost three fourths of the growth needed in cereals production to the year 2000 must come from productivity gains on existing croplands.[6/] Therefore, CIMMYT's primary program thrusts will be aimed towards increasing the productivity of existing areas. In some measure production increases will result from additional cropping intensity, but the most important source must necessarily be through yield increases.

In reviewing its plans for the 1980's, CIMMYT tried to cast these against the background of the 21st century. Food demand and production projections to the year 2000 have been made by several agencies. Such projections are understandably precarious. Even so, and while not in precise accord, they show a world characterized by markedly greater demands for cereals.[3,6/]

GOVERNMENT GOALS AND CIMMYT

The problems of meeting the growing global demand for food can be seen from two related perspectives. First, and this perspective is made ever more relevant by urban growth trends, is a simple emphasis on increasing production whatever its source. Larger total production adds to the quantity of food available to urban cereals consumers and dampens price increases or actually lowers prices. Thus, production increases in, for example, Argentina are relevant to urban consumers in western Africa. This is especially important for the urban poor, who spend a high proportion of their incomes for food and rely heavily on cereals for energy and proteins.

At the same time it is evident that a large portion of global cereal consumption still occurs among the rural poor. Production increases by those poor will, at once, permit a direct increase in their consumption of cereals and, through markets, of other commodities as well.

Some governments—those with adequate foreign exchange—will emphasize an assured supply of cereals, whatever its source. But even if major producing areas could substantially increase their production and the quantities available for export, the realities of world economics have shown that the food-deficit, low-income countries of the developing world stand little chance of achieving greater food security for their people except through increasing per capita national production. Hence, these governments—some 40 to 50 in number—are placing an increasing emphasis on accelerating domestic production. Many are emphasizing higher production by resource-poor producers, i.e. by their own rural poor.

CIMMYT must ensure that its program activities help to increase global supplies of cereals as well as domestic production in low-income, food-deficit countries. Not only will the nature of these demands differ from country to country, as some will focus simply on production while others specify production among various classes of farmers, but their national research and production programs will differ notably in their own capacities. CIMMYT must be sensitive to these differences if it is to serve national programs effectively.

A LOOK AHEAD

In organizing its expected program priorities for the 1980's, CIMMYT is influenced by its own accumulated experience, by counsel from development assistance agencies, by its close communication with scientists and administrators in national programs, and by the broader perspectives set forth by CGIAR—related entities. The following chapter provides some detail on the activities which CIMMYT plans to emphasize during 1981-1986. It will be evident that the attainment of yield stability is a dominant consideration in CIMMYT's plans, complementing but nevertheless exceeding, the attention given to increasing maximum genetic yield plateaus.

Program plans, which continue to evolve, are quite consistent with the implications of CGIAR thinking and with the research priorities described by TAC.[7/] All take the long run view, looking on international agricultural research as a continuing function of support and service to national programs and all emphasize the importance of improving average production levels and yield dependability. CIMMYT and TAC concur in the idea that the generation of superior genetic materials is the area where international agricultural research can make the most important contributions to food production. With respect to the degree of adaptability of germ plasm, (e.g. the need for balancing the widely adapted with the locally adapted) both concur in the view that the balance will depend on the comodity considered, the status of research, and the capabilities of national programs. However, both, CIMMYT and TAC place increasing emphasis on distributing early generation materials with national programs selecting for local adaptation, and both endorse the concept of regional programs to facilitate cooperation among national research systems.

TAC and CGIAR documents emphasize the importance of integrating farming systems research into the work of national programs and that of international centers. While CIMMYT has no formal program in farming systems research, it nontheless shares this concern. In all of its production-oriented activities and in its training, maize and wheat are viewed as part of larger farming systems. CIMMYT has always stressed the need to clearly recognize the important competitive and complementary farming activities as maize and wheat technologies are formulated and recommendations are framed. This farming systems perspective has long characterized CIMMYT's view of its crops and will continue to do so in the future.

But even with carefully focused research, increases in developing country production will not come easily. There are no technological panacea for solving the food problems of developing world in the years ahead. Indeed, carefully focused agricultural research is but one of the elements essential to success. Beyond that, massive investments will be required, particularly in irrigation, drainage and flood control, in fertilizer facilities, in seed production and distribution facilities, in agricultural credit, and in better marketing infrastructures and institutions. But this, too, will be insufficient unless carefully tailored and orchestrated policies are applied. The formulation of such policies will require a much better integration of the insights of policy makers, administrators and scientists.

Most of these issues must be dealt with by other institutions—national and international—but CIMMYT must be cognizant of their implications for the development and diffusion of improved technologies. Moreover, to the extent that CIMMYT's experience and competence are relevant to the problems, the Center will offer assistance where requested.

REFERENCES CITED

1. FAO Production Yearbooks, 1971-78.
2. Worldwatch Paper 5, "Twenty-Two Dimensions of the Population Problem"; Lester R. Brown, Patricia McGrath, Bruce Stokes, 1976.
3. IFPRI, "Food Needs of Developing Countries: Projections of Production and Consumption to 1990." Published 1977.
4. UN Conference on Desertification Nairobi, Kenya, Aug. 29–Sept. 9, 1977. "Desertification: An Overview."
5. Worldwatch Paper 24, "The Worldwide Loss of Cropland," Lester R. Brown, 1978.
6. UN Conference, Rome, November 10-19, 1980 "Agriculture: Toward 2000." Published 1979, draft document.
7. TAC Priorities on International Agricultural Research, 1978.

CHAPTER FOUR

CIMMYT IN THE 1980'S

OVERVIEW

This chapter describes CIMMYT's intentions for the period 1981 to 1986. The discussion is framed around the center's major activities in germ plasm, training, procedures, and consultation. Before treating those themes, however, it is essential to reemphasize that CIMMYT is a single link in a chain which runs from basic research through to the verification of recommendations under farmer circumstances and getting improved technology into use. One part of this long process, related to basic research, will be treated in more detail later in this chapter. A second critical link, that to national research programs who are CIMMYT's principle clients, is the theme of the remainder of this introduction.

In the final analysis, national programs are responsible for formulating technologies and recommendations. CIMMYT's role is to make available products and services which facilitate effective national action. To play its own role effectively, CIMMYT must be cognizant of the differences among national programs, tailoring its offerings to meet the various needs of different programs and the varying needs of a given program.

Some of the better established national programs have formed close collegial research relationships with CIMMYT. Senior scientists in these programs rely on CIMMYT for germ plasm which they can incorporate as elements into on-going breeding efforts. Given the often severe limitations on funding, they also look to CIMMYT to facilitate professional exchange among colleagues facing similar problems. Their own work is carried directly into CIMMYT's programs and made available to researchers in other parts of the world.

At another level, many national programs find it advantageous to look to CIMMYT as a potential source of improved varieties for direct introduction to farmers. For one reason or another—e.g. inadequate funding, inexperienced staff, constricting work rules—these programs cannot sustain efforts to adapt materials from international centers, but find it preferable to select directly from the international nurseries. These programs also find CIMMYT's training and consultation of substantial value and, as well, look to CIMMYT for help in organizing and focusing efforts to formulate recommendations.

Finally, some national programs face such severe research constraints that they must look to CIMMYT to take the lead in selecting appropriate materials from international nurseries. These programs rely heavily on CIMMYT for training and other forms of support as well.

CIMMYT hopes that all national programs progress toward the more collegial relationship featured with the well-established research institutions. This progress, if attained, will have implications for the thrust of CIMMYT's efforts. It implies relatively less attention to finished varieties and more emphasis on early generation materials. In the longer run it might well also mean more relative attention to the questions underlying the development of crop improvement and crop management, with greater relative emphasis on unravelling the more basic dimensions of disease, or insect resistance and tolerance to drought and other agro-climatic stresses.

It must be noted, however, that this evolution of national programs, with its concomitant implications for CIMMYT's emphasis, is not a smooth one. Not only do national programs vary among themselves, but as well, many experience an ebb-and-flow in their capacities. CIMMYT must recognize these changes in formulating its own plans. Even during our own short institutional history, several national programs have moved towards self-sustaining performance only to be decimated by resignations, transfers, promotions, budget restrictions, or political re-organizations. And reflection compels the view that this process will affect still other national programs during the period of this plan, reinforcing and adding urgency to CIMMYT's need to know its national program clients well and to maintain flexibility in tailoring CIMMYT's offerings to their changing requirements.

In contemplating the evolution of national programs it is important to recognize their sensitivity to external forces. At this time, for example, energy costs, with their implications for overall government budgets and for operating costs everywhere, are having a notable impact on research and production programs. As the real value of budgets decline, it is more and more difficult for national programs to sustain their activities. One potential consequence is that those programs must rely more and more on the international centers for improved germ plasm and, in critical cases, for even more help with selection.

GENERAL CROP IMPROVEMENT DEVICES USED BY CIMMYT

In discussing the procedures used by CIMMYT in maize and wheat improvement, several mechanisms and relationships—and the program philosophies underlying them—are sufficiently similar in both programs to be introduced collectively. These include the germ plasm banks, international testing networks, regional programs and collaborative research arrangements.

GERM PLASM BANKS

CIMMYT maintains germ plasm bank units for maize, wheat, barley and triticale as a service unit for researchers. These bank units maintain, catalog and regenerate seed and handle special seed requests and shipments to users. The maize germ plasm bank is CIMMYT's largest with about 13,000 entries in cold storage gathered from more than 50 countries.

The wheat program up to 1980 has only operated a very minimal short-term cold storage seed maintenance facility for its crops. Over the years, CIMMYT has greatly increased the scope and extent of its worldwide collaboration. This has resulted in an increasing volume of breeding material which should be maintained by CIMMYT. This is particularly true for triticale, in which CIMMYT has one of the world's largest breeding program. In addition to germ plasm maintenance, *per se*, the wheat program needs additional storage space for actual working collections and for small-scale seed supply increases for other collaborating programs. For these reasons, CIMMYT with financial assistance from Japan, is building a new wheat germ plasm bank facility slated for completion in 1981.

INTERNATIONAL TESTING NETWORKS

The contributions to world food production resulting through the international testing networks developed over the last 25 years have far exceeded the dreams of the original founders. Through these testing networks, high yielding cereal varieties with wide adaptation and increasing resistance to crop diseases and pests have been developed at an accelerated pace. This network of international testing and data sharing has served as a unifying thread to bring together the work of thousands of scientists and hundreds of organizations worldwide and has led to the establishment of the interrelated systems which now exist.

CIMMYT acts as the hub in the development, assembly, distribution and data processing of international trials and nurseries for its crops. Each year improved germ plasm emanating from the international networks of collaborating breeders is assembled in Mexico into more than 3000 sets for testing at hundreds of locations worldwide. Scientists growing CIMMYT-distributed germ plasm record information on yield performance and other important production characteristiscs which is then sent to CIMMYT for data compilation, analysis, and reporting to testing network participants.

The observations made from each annual international testing cycle are extremely important in crop improvement research. In an overall way, the information reported is a measure of the research progress in maize, wheat, barley and triticale improvement programs. Nursery observations also provide valuable breeding information to guide future network crossing and selection programs.

In the CIMMYT-advocated breeding strategy, large numbers of different germ plasm are planted together at a range of sites under as uniform conditions as possible. National collaborators review the range of available experimental trials and select those nursery sets that are useful to their purposes. In this breeding strategy, the skill centers around the collective eye of scientific teams who evaluate experimental materials for a multitude of yield and production dependability traits. For it is only under local conditions that the real value of a particular variety can be determined. Therefore, it is within the national programs that varieties become actualized, named and released.

National participants also use the international testing network to evaluate the performance of promising national materials, particularly in terms of their resistance to certain diseases and pests of potential damage locally if higher build-ups were to occur in areas planted to susceptible varieties.

The information gathered each year from widespread multilocational testing also is invaluable to CIMMYT breeding programs. Drawing on this information, CIMMYT scientists have been able to assemble and develop a wide range of broadly-adapted material and to maintain a continuous flow of new and/or improved genetic material to national programs.

During the 1980's, CIMMYT expects the free exchange of germ plasm among scientists to continue, subject to possible restrictions due to breeders rights and plant quarantine problems. Several shifts, already underway in 1980, in germ plasm development and delivery are expected to continue. One is toward further classification of germ plasm into smaller, more regionally-targeted nurseries and trials. Regional nurseries have proven to be very effective in developing materials with resistance to particular disease problems or with tolerance to certain problem soils and other agro-climatic stresses. They also are being used in the wheat program as disease surveillance mechanisms to identify potential disease epidemics in important small grains production areas.

These regional nursery subsets remain closely coordinated with the more broad-based international testing network. Superior germ plasm selected from regional nurseries are crossed back into the general CIMMYT germ plasm base to continuously infiltrate more desirable genes into all the materials undergoing improvement.

REGIONAL PROGRAMS

The growing number of countries participating in the international testing networks led CIMMYT in the 1970's to explore new strategies to sharpen the Center's understanding of crop production problems in developing countries and to assure good communication with collaborating agricultural scientists. It became obvious that an efficient method to monitor the international nurseries, develop regional screening trials and to respond to the mounting requests to CIMMYT staff for assistance in strengthening national programs was through the assignment of core staff to regional programs. During the 1980's, the major growth activity in these programs will be in encouraging more production-oriented research by national collaborators.

CIMMYT agronomists assigned to all regional programs will place particular emphasis on supporting research on weed control, more efficient use of fertilizers and other important cultural practices. Regional staff will assist national programs in the evaluation of integrated control methods of weeds, diseases and insects. They will also keep abreast of research on minimum tillage systems and forward relevant research data to collaborators.

Regional economists also are involved with national programs in production-oriented and policy-related research. One part of the information generated, a joint product of biological scientists and economists working in national programs, is the data and analysis related to the on-farm research. This information is immediately available for orienting further research on technologies and is also brought to the attention of national policy makers. CIMMYT economists will place more emphasis on analysis of this data for policy makers concerned with the development and diffusion of improved technologies.

Regional staff are integral members of the maize, wheat and economics programs and report administratively to program directors (CIMMYT has no separate director for outreach). They are responsible for pursuing those program objectives most effectively accomplished through such a deployment. These are:

1. Primary research leadership on certain types of production problems in which a particular region, because of its location, is best suited to conduct the research;

2. Monitoring of international nurseries and trials, and coordination of more area-specific screening nurseries made up of locally adapted germ plasm;

3. Development of regional small grains disease surveillance and early warning systems;

4. Improvement of communications between national scientists within and across regions;

5. Expansion of training and educational opportunities to assist national programs in staff development;

6. More effective feedback to CIMMYT staff on important production problems to better orient crop improvement and in-service training programs;

7. Improvement in consultation services to national programs, both by CIMMYT and by other agricultural institutions;

8. Motivation of local scientists and governments to increase production-oriented research activities.

Although one blueprint cannot fit all regions, CIMMYT believes that every major maize and/or wheat growing area can benefit from a regional program. Wherever possible CIMMYT seeks logistical support for its regionally assigned staff from sister international institutes or collaborating national institutes.

COLLABORATIVE RESEARCH

There are certain types of maize and wheat improvement research in which other institutions have a comparative advantage, e.g. because of the presence of diseases or insect pests, or because of special expertise or equipment. In these cases, CIMMYT seeks to develop collaborative research links with those centers that are better situated or suited to pursue these activities.

An increasing number of collaborative research projects, in both developing and developed country research institutions, are emerging and CIMMYT expects that these arrangements will become even more prevalent in the years ahead. CIMMYT's involvement will include the sharing of germ plasm, the use of CIMMYT experiment stations in shuttle breeding type arrangements, the exchange of scientific information, and the direct research cooperation of CIMMYT staff. Certain types of collaborative research will continue to be partially financed from CIMMYT's core program budgets. Other types may be partially supported by special project funding.

IARC'S—During the 1980's CIMMYT will work cooperatively with IITA on maize improvement in tropical Africa and with CIAT in maize improvement in South America. CIMMYT's wheat program is most closely associated with ICARDA, which has a regional mandate for wheat and barley. It hopes to jointly staff with ICARDA the North-West African Regional Wheat Program. In addition, ICARDA has asked CIMMYT to station a wheat breeder at ICARDA during the 1980's. CIMMYT also anticipates developing stronger cooperative relationships with IFPRI on policy-related issues of maize and wheat; and back-up support to ISNAR on the organization of agricultural research and production systems.

Other Development Assistance Agencies—CIMMYT has a long history of cooperation with many development assistance agencies (such as FAO, UNDP, World Bank, IDB, IADS) who are engaged in bilateral programs with developing country governments. The Center expects to continue to provide such back-up support (as is possible) in germ plasm, consultation, in training to agencies involved in bilateral projects, and in identifying important restrictions on production.

MAIZE IMPROVEMENT PROGRAM, 1981-1986

INTRODUCTION

Among cereal crop species, *Zea mays* (maize) possesses the highest genetic yield potential, has enormous genetic variation and is adapted to an extremely wide range of climatic and soil conditions. It is a plant of many productive uses. In addition to its value as a foodstuff, and as the major animal feed, maize also has many industrial uses such as starch, cooking oil, sweeteners, and more recently, biomass and gasahol.

In most of the developing countries in which maize is an important food crop, yields are very low averaging about 1.5 tons/ha. Although one-half of the world's maize area is planted in the developing countries of Asia, Africa and Latin America, only one-fourth of the world crop is harvested there. In general, most of the maize produced in these countries is as a subsistence crop grown usually under rainfed conditions characterized by seasonal problems of moisture stress, poor weed control, and usually on soils of low fertility.

CIMMYT's maize program is designed for a multidisciplinary attack on the wide range of problems that have restricted maize production in the developing world.

The population improvement strategy followed today by CIMMYT draws on the methodology work of CIMMYT's predecessor organizations as well as on the research carried out during the first years after CIMMYT's establishment. By 1970, a number of populations with different characteristics had been developed and were being tested and shared with a number of national collaborators. Next, the range of genetic materials included in the population improvement program was widened to meet the broader requirements of CIMMYT's expanded global responsibilities.

In 1970, CIMMYT began to test these materials in selected regions of the world. Such trials provided more accurate data on the adaptability of various materials in different areas. Some of the stronger national programs began using CIMMYT materials in their own breeding programs. This was truly a significant achievement, as most national programs had been working with limited, narrow-based maize germ plasm and now had access to superior, broad-based maize germ plasm. In 1974 the systematic international testing system in operation today was organized and began serving national programs.

Two other significant developments began to take shape at the beginning of the 1970's. First, CIMMYT acquired a network of experiment stations in Mexico that represented several appropriate agroclimatic conditions where maize improvement work could be done with greater precision. Secondly, the dimensions of the maize improvement program were further expanded to include nutritional aspects (i.e. improvement of protein quality in maize). This became a parallel and integral part of CIMMYT's total maize improvement program.

CIMMYT begins the 1980's with an overall maize improvement strategy that can: (1) properly service maize-growing areas characterized by different levels of capacity; (2) simultaneously serve as a mechanism for continuous improvement of maize germ plasm as well as a delivery system to and from national programs; and (3) meet the needs for exploratory and innovative maize research.

Each year, germ plasm newly arriving at CIMMYT or entries drawn from the CIMMYT germ plasm bank are tested and superior materials added to the corresponding gene pools. These pools are constituted on the basis of maturity period (early, intermediate, late), by grain color (white-yellow), by kernel type (flint-dent); and by area of adaptation (tropical, temperate, highland). After recombination and improvement, superior progenies from these pools are moved to advanced populations. Superior progenies from the advanced populations are combined into experimental varieties and supplied to national collaborators for use in research and production programs.

Germ plasm from temperate and tropical areas continue to be crossed and brought into gene pools undergoing improvement to broaden the genetic base and hopefully to improve the yielding ability and/or stability of yield of different maize types. Tropical materials should benefit from the genes in temperate zone materials for good agronomic type and yielding ability. Temperate materials, on the other hand, should benefit from the introduction of new variability into their relatively narrow genetic bases, thus increasing their stability of yield.

The temperate maize germ plasm from the USA and Europe has been a source of superior yield genes and has been used in varying degree by national programs in developing countries. But the gene base in USA and Europe is also quite narrow, and the maize researchers there are genuinely concerned. In 1978, CIMMYT began to assemble three new gene pools adapted to: the extreme northern range of the temperate region; the southern temperate range; and the intermediate belt of the temperate region. The objective of these pools is to introduce exotic germ plasm into temperate base materials, which in turn will serve as a mechanism to move superior genes from temperate germ plasm into tropical and highland germ plasm. This approach has shown excellent promise for worldwide maize improvement and will be pursued energetically in the 1980's.

The multilocational and international testing system, followed by recombination of superior materials, was specifically designed for continuous improvement in the adaptability and yield dependability of maize populations, as well as for identification of superior germ plasm for use by national programs. Superior germ plasm developed within the collaborative system is now in use by most national breeding programs, with an increasing number of high yielding varieties being released and used by farmers.

Within this general system, a multi-trait breeding strategy is pursued, with variable relative weights given to the different traits to be improved according to the problems affecting different maize populations. This flexibility allows for differing selection criteria and weights for each individual population undergoing improvement. In one population, perhaps greater resistance to a particular disease or insect problem and greater earliness are particularly important goals. Thus, in that population, greater selection pressure will be applied for these particular traits. In another population, the problems and priorities would be different.

CIMMYT believes that its current system of population improvement offers the greatest service to the greatest number of national collaborators. The seeds of open-pollinated varieties produced through this population improvement system can be saved from one season to another, and farmers can help in their spread. Hybrid seed, on the other hand, must be replaced every season to maintain its productive advantage. Any national program that has the technical expertise and the infrastructure for the production and distribution of hybrids can use CIMMYT materials to develop hybrids, and probably more rapidly and efficiently than using other more traditional methods.

YIELD DEPENDABILITY

In most developing countries, maize is grown usually as a rainfed crop, under varying conditions of moisture stress, with poor weed control and usually without adequate plant nutrition. Since the maize growing areas found in the developing world represent a wide range of environments, it would be prohibitively expensive (and inappropriate) for CIMMYT to attempt to develop specific materials for each of these micro-environments. Therefore CIMMYT attempts to develop wide adaptability into each population (plant group) under improvement. This strategy, CIMMYT believes, provides the most effective system—cost-wise and biologically—to increase the yield dependability (and yield potential) of maize grown in the developing world.

DISEASE AND INSECT RESISTANCE

Maize germ plasm contains many genes for resistance to diseases and insects. By gradual accumulation of these genes in selected populations, the maize crop can increase its natural tolerance to pest hazzards. By achieving greater genetic resistance to diseases and insects, these new maize varieties can benefit all classes of maize farmers, and especially the smaller, poorer farmers in developing countries. This improved genetic resistance can lead to significant increases in maize production in many areas, which is lost today through disease and insect damage.

Disease Resistance—A primary CIMMYT program thrust in the 1980's will be to improve the genetic resistance of different maize types to serious yield-debilitating diseases. As part of the central multi-trait improvement program, CIMMYT scientists are working on resistance to stalk rot, ear rot and foliar diseases. This work will continue in the 1980's. Other types of disease problems that are less general must be conducted in areas affected with the problem. These are handled through special collaborative research projects.

Starting in 1974, three collaborative breeding projects were organized between CIMMYT and six national maize programs to jointly develop germ plasm with resistance to three major diseases of maize. These are: downy mildew caused by a fungus found mainly in South and Southeast Asia, but now spreading in Africa and Latin America; maize streak virus, disseminated by a leaf hopper throughout tropical Africa; and corn stunt, a disease also spread by a leaf hopper in tropical Latin America.

Since the benefits from developing germ plasm more resistant to these diseases will accrue to countries beyond those directly involved, CIMMYT commits staff time and money toward the operation of these programs. The projects are built around an improvement strategy whereby the screening for resistant families is done by national programs at local locations during one cycle, and improved in Mexico for general agronomic characteristics in the next cycle. This technique is proving to be an extremely efficient breeding strategy to rapidly develop high yielding varieties with greater disease resistance and will continue in the future.

By 1980, the collaborative research programs for downy mildew and corn stunt resistance were well underway. CIMMYT maize scientists feel quite confident that in the 1980's varieties carrying far greater genetic resistance than ever before can be ready for release to farmers in affected areas.

The work on streak virus, a serious problem for tropical Africa, requires insect-rearing facilities located in several affected areas of Africa. This is because streak virus is carried by leaf hoppers and therefore, the insects must be artificially reared to adequately infect maize populations undergoing improvement. IITA already has such a facility for work in West Africa and CIMMYT plans to actively seek international financial support to establish another facility in East Africa so that research to overcome this significant production problem in that area can make better progress.

Several new collaborative disease research programs may be necessary in the 1980's to improve the resistance of maize materials to other important disease problems. The next likely research target will be to develop greater resistance to "late wilt", a serious yield-limiting factor in India, Pakistan, Egypt, and Turkey (and probably throughout North Africa). Again, the same shuttle breeding strategy with strong national maize program partners will be followed.

CIMMYT will add new practical pathology training programs during the 1980's on methods of disease inoculation and on the operation of disease screening nurseries. This training will be held in collaboration with national programs. CIMMYT staff will assist in this training.

Insect Resistance—Insect damage is another important yield-limiting factor in tropical maize. The breeding for resistance or tolerance to insects continues to be a major CIMMYT research thrust during the 1980's. Considerable progress has been made in developing resistance to fall army worm in two maize populations.

During the latter part of the 1970's CIMMYT developed its insect—rearing facilities as well as new techniques for infesting maize plants with insect larvae for uniform screening for insect resistance. At its Mexico stations, CIMMYT can work on several insects (fall armyworm, ear worm, sugarcane borer and South Western Corn borer) which cause economic losses in maize, particularly in Latin America and the Caribbean. Insects not found in Mexico which cause serious production losses in other regions and continents must be studied where the insects naturally exist.

Before CIMMYT moves beyond the current insect resistance work in Mexico, a series of field tests will be conducted internationally to determine the extent of resistance developed to fall armyworm in these materials. If this resistance withstands field tests, CIMMYT will begin to move aggresively on expanding its insect resistance work during the 1980's, forming regional types of collaborative research projects with strong and strategically situated national programs in Africa and Asia. The insects most likely to receive future research attention are *Sesamea* (Asia, Africa), *Chilo* (Asia), European Corn Borer (Asia) and *Busseola* (Africa).

In entering into such collaborative research projects, CIMMYT will seek funding to help national programs develop the necessary insect-rearing facilities and to effectively operate each project. CIMMYT anticipates committing staff time to assist with these projects. The screening for insect resistance will be carried out in national programs during one cycle followed by a cycle in Mexico directed at general agronomic improvement of the resistant selections. Again, CIMMYT will offer training opportunities to national program staff in techniques for rearing insects and properly managing screening nurseries.

INCREASING TOLERANCE TO AGROCLIMATIC STRESSES

The international testing system (and subsequent recombination of superior families) provides a built-in mechanism to improve adaptability and stability under various agroclimatic conditions. Drought is one such situation.

Drought Tolerance—Throughout the tropics drought often causes sizable yield reductions in maize. Drought stress is most often caused by irregular distribution of rainfall and by soils with low water-holding capacity.

A special project was initiated in 1977 to attempt to develop techniques capable of identifying drought tolerant genotypes. Preliminary data collected up to 1980 indicate that it is possible to select genotypes with improved yielding ability under stress conditions without losing their capacity to perform well under adequate moisture regimes.

In the 1980's, CIMMYT plans to expand this aspect of the program to test such findings under a wide array of field conditions and with more types of material. CIMMYT also hopes to develop stronger collaborative arrangements with other institutions (e.g.Plant Stress and Soil Moisture Conservation Laboratory, Lubbuck, Texas) to explore: plant mechanisms involved in materials showing tolerance to variations in moisture regimes and the possibilities of seedling screening for specific drought mechanisms.

IMPROVING YIELD EFFICIENCY IN TROPICAL MAIZE

Tropical maize is plagued by several yield-limiting factors. Generally, the plants are too tall, and thus do not make efficient use of fertilizer and space (have to be grown at low density), and they often lodge (fall over) at maturity. In some parts of the tropics, maize is grown as a mixed crop with beans, and these tall plants are not suitable for such association. The tall tropical maize plant also is a grain-inefficient plant, because a greater part of energy goes into stover. CIMMYT is putting more emphasis on reducing plant height, while selecting for yield and other desirable agronomic characters. CIMMYT's maize materials today are shorter, earlier, and yield better than those in the original base populations. CIMMYT is now providing the national programs with more manageable, fertilizer-responsive maize plants, with the promise of greater yield per hectare.

Using a system of recurrent selection, almost solely based on shorter plant height, CIMMYT scientists have achieved a rapid reduction in plant height producing a tropical maize plant that is almost half the height of the original base population and with better grain efficiency. This new plant has a grain-to-stover of 1:1, compared to 35:65 in the original parents. The total dry matter yield per hectare of this short-statured material is the same as the original tall material, but there now is significantly more grain in the total dry matter (experimental yields were in the 6-8 ton/ha range).

Within tropical maize materials, the reduction of foliage and the size of the tassel, along with selection against barreness (particularly at higher densities and under stress conditions) also are being looked at as processes for increasing yield efficiency.

In addition, the introduction of temperate germ plasm into the tropical gene pools and subsequent tropical x temperate germ plasm development and recombination may result in the development of tropical maize types which carry the most desirable of the temperate zone plant architecture and yield efficiency characters.

CIMMYT scientists are convinced that research during the 1980's will provide a substantial boost in the genetic yield potential of tropical maize.

EARLY MATURING VARIETIES

Considerable interest exists among national collaborators for CIMMYT to develop earlier maturing, high yielding materials for developing country production conditions. Such materials are desired either to fit into more intensive annual production cycles, mixed cropping situations, or for areas where moisture is limited and cannot sustain longer-season varieties.

CIMMYT believes that there is a need for such materials and recognizes that many of the traditionally available short-season materials are particularly low-yielding. The CIMMYT program already has many different higher yielding populations with short, intermediate and long season maturity characteristics to fit different production requirements. New and promising early-maturity materials contained in the germ plasm bank and from new temperate x tropical gene pools are being fed into the more advanced populations for more intensive selection and distribution to national programs. During the 1980's, early materials with high yield potential will be available for those area programs where greater earliness is of paramount importance. Using materials distributed through the international testing program, national scientists make more intensive selection for earliness in desired populations.

IMPROVING NUTRITIONAL QUALITY

Since its inception, CIMMYT has been convinced that maize must play an increasingly important role as a human food, if the world's expanding population—particularly in the low-income, food-deficit countries—is to be fed. For more than 10 years, scientists at CIMMYT have been working to improve the quality of maize protein. The progress in this area has been one of the truly remarkable stories in plant breeding research of the last 20 years. It has resulted in a number of high yielding populations of different grain types that look and taste like normal materials, and yet have substantially better nutritional quality than traditional maize. The yields of the nutritionally superior maize populations are comparable to some of the best normal materials in the CIMMYT program.

CIMMYT is convinced that it is genetically possible to combine high yield and high nutritional quality. It intends to actively seek national program partners to launch campaigns to get some of the more advanced quality protein maize populations into commercial production in developing countries during the 1980's. This nutritional improvement in maize can be particularly important to groups vulnerable to undernutrition such as poverty-stricken mothers and children. It also offers important nutritional gains in the feed used for the production of nonruminant animals.

CIMMYT will continue to improve nutritional quality maize during the 1980's. Added disease and insect resistance will be developed. The stability of appearance (hard endosperm versus soft, chalky, opaque grain) and performance over various agroclimatic areas will continue to be improved. Other remaining problems, such as the slow drying of opaque-2 grains as compared to normal types, will be intensively studied. Collaborative projects with more fundamentally-oriented research institutes will be sought to unravel some of the more basic aspects of the remaining improvement problems.

CIMMYT believes that it is entirely feasible that in 25 years time, all improved maize germ plasm grown throughout the world for direct human or non-ruminant animal consumption may carry the mutant genes for higher protein quality as a standard genetic character.

SPECIAL ISSUES

GERM PLASM FOR SPECIAL PRODUCTION PROBLEMS

In general, maize has a high degree of tolerance to many soil problems. It will grow in very low (4.5) and very high (9.0) pH conditions. The existing international testing program is designed to identify the variation found in maize germ plasm and to develop varieties with even greater tolerance to stress problems in those populations which will serve such problem areas. This strategy will continue in the 1980's.

It has been shown that maize genotypes differ in their ability to tolerate high aluminum ion levels in tropical soils, and these differences are heritable. Since 1976 CIMMYT has been working with certain national programs, Brazil in particular, to develop materials with greater tolerance to the aluminum levels found in some tropical soils. This work will continue.

There are large tracts of tropical soils where maize is grown and where the availability of phosphorus is quite low. Recent studies done at Cornell University and elsewhere with CIMMYT germ plasm seem to indicate genotype x phosphorus level interaction in both uptake and transport by the plant. CIMMYT hopes through multilocational testing to identify superior genotypes for soils with a high phosphorus-fixing capacity.

CIMMYT is sometimes questioned about the feasibility of developing varieties with greater tolerance to saline soils such as those increasingly found in many irrigated areas. CIMMYT believes that this situation must be corrected through engineering solutions, such as drainage projects, and that plant breeding cannot offer a viable solution.

Likewise, CIMMYT views attempts to develop maize varieties for chronically waterlogged soils as offering scant potential for a research payoff. Rather, soils suffering from these situations should not be planted to a crop such as maize.

WIDE CROSSES

Maize, as previously stated, possesses great genetic variability, and therefore, potential for improvement. While the primary thrust of CIMMYT's maize improvement program is to take advantage of the variation found within existing maize germ plasm, CIMMYT has been exploring the possibility of transferring to maize various desirable traits found in other genera. Two species are being used in this intergeneric crossing program: tripsacum, a wild relative of maize which shows resistance to a wide range of diseases and pests which are a problem to maize and sorghum, which has greater tolerance to drought and to waterlogged conditions than maize.

To date, CIMMYT scientists have been able to breakdown to some extent the crossing barriers between these alien genera. A few maize x tripsacum and maize x sorghum hybrids have been produced. Although no firm evidence exists that desirable genes from alien genera can be transferred and maintained in maize, CIMMYT believes that this current line of research should be continued further. Stronger cytological competence, a vital dimension lacking from the past research activities, has been added to the program to learn more about what is happening to the chromosomes involved in these wide crosses. In addition, CIMMYT is taking an active role in encouraging more basic research in wide crosses by other research centers.

WHEAT IMPROVEMENT PROGRAM, 1981-86*

INTRODUCTION

CIMMYT's Wheat Improvement Program has expanded its scope over the last 14 years to include research on bread wheat, durum wheat, barley and triticale. The program is organized into commodity-oriented sub-programs supported collectively by additional program units (pathology, new germ plasm development including wide crosses, milling and baking, agronomy, international testing, and training). Regional programs serve as a principal linkage mechanism between resident research activities and those of collaborating national programs.

Since CIMMYT attempts to serve all small grain producing areas, with the primary emphasis on the developing world, it endeavors to maintain the widest possible variation in its germ plasm so that material is available for all important production areas.

Toward this end CIMMYT scientists, drawing on data from the international nurseries as well as their own observations, make thousands of crosses and evaluate tens of thousands of offspring plants each year. Within Mexico, the wheat program depends primarily on two experiment stations in Mexico for most of its work. The first is an irrigated winter station (belonging to INIA) situated in northwest Mexico (40m altitude, 27^{o} latitude) where seeds are sown in November when the days are getting shorter. The second is located in a high, rainfed area of the Central Mexican plateau (2,650 m altitude, 19^{o} latitude) near the city of Toluca; seeds are sown in May as the days are getting longer. These widely differing environments allow CIMMYT scientists to select materials exhibiting good performance—and therefore broad adaptation—at both locations. In fact, only those surviving the rigors of both environments can move forward. This system permits two cycles of selection each year.

CURRENT STATUS OF GERM PLASM

BREAD WHEAT

CIMMYT currently distributes a very broad range of high yielding germ plasm in bread wheat with good industrial quality which collectively carries resistance to the major diseases of principal production areas. The successful introduction of varieties based on CIMMYT materials is indicative of the broad suitability of the germ plasm. While yield, *per se*, is being gradually increased, dependability of yield has a priority position in the program. Weaknesses in the germ plasm are primarily in the disease sector (described in greater detail later). Considerable progress has been made on adaptation to problem soils and dry conditions and continued efforts will be pursued in improving these characteristics. Very specific problems such as heat tolerance, cold tolerance and insect resistance, where necessary, also will receive increased attention.

---

* When the term "Wheat Improvement Program" is used in this report, it will refer to all four crops; other statements will be directly identified with one particular crop improvement program.

DURUM WHEAT

Yields of durum wheats have markedly increased in the last decade. Varieties with CIMMYT germ plasm are being grown widely in Mediterranean Basin countries and in South America. Present advanced lines and derived varieties have high yields, good industrial quality and good adaptation. Maximum yield potential continues to rise and is similar to the best bread wheats. Leaf and stripe rust resistance in CIMMYT durum lines is extremely good, but there is a need to improve resistance to stem rust in certain durum areas. Additional resistance to several other diseases (described later) also is needed. For other areas, added cold tolerance is being sought.

BARLEY

Current CIMMYT materials have greatly improved straw strength, earliness coupled with high yield, semidwarf habit, and are generally improved plant types. A range of high lysine materials are available with suitable grain characteristics. There also is a wide range of both hulled and hull-less grain types, suitable for barley-growing locations. These traits were consciously emphasized in the early improvement work by CIMMYT, since in many cases, the target production regions were the semi-arid areas of the Middle East and North Africa. In these dry environments, diseases are not a serious problem. However, now that these improvements are well underway, a shift is being made in the program to concentrate on barley disease problems in other areas.

Presently, CIMMYT's barley material is susceptible to a variety of different diseases (described later). Work on many of these disease problems will be done in Mexico. In a few cases, collaborative projects in other countries will be needed so that screening can be done in disease hot spot areas.

In the hull-less types, CIMMYT scientists are searching for materials with less exposed embryos so that the seed damage presently occurring (resulting in reduced germination) may be avoided. Added drought tolerance also is being pursued.

TRITICALE

During the last ten years, the progress made in improving triticale has been spectacular. Among the newer lines are types with suitable plant characteristics for high yields. Triticale is not intended to replace wheat, except in those areas where it has aproductive advantage. On very acid soils, such as those found in the lower ranges of Himalayas, the highlands of East Africa, and the **campos cerrados** of Brazil, triticale frequently yields up to twice as much as the better wheats.

Triticale is receiving its first commercial acceptance in several developed countries where some 350,000 hectares are now grown. CIMMYT considers that it is logical for these developed countries to be the first to enter into commercial triticale production since their large pools of scientific manpower have been able to carry out the attendant research required to get triticale into use.

Nevertheless, such countries as Mexico, Argentina, Brazil, Chile, Kenya, Tanzania and India are becoming increasingly involved in national research and production of triticale and CIMMYT believes that the crop will take its place among the cereals grown in the developing world during the 1980's.

A much expanded program for producing octoploid (bread wheat x rye) triticales will occur during the 1980's, although the existing work on hexaploids (durum x rye) will also continue. The octoploid form of triticale may lead to improved seed type and baking qualities, a more semidwarf plant habit, and greater earliness. If octoploids contain these improved characters, they may become more widely grown than hexaploid types in the next ten years.

YIELD DEPENDABILITY

CIMMYT wheat germ plasm has at present a relatively high level of resistance to the principal diseases. However, since the resistance to all diseases is not equally high, CIMMYT is placing greater attention on the resistance levels against certain diseases still considered to be deficient. CIMMYT always has warned of dangers of widespread disease attack in large areas which are planted only to one or two pure-line varieties. Therefore, in addition to the search for new genes to confer greater yield dependability, concepts (to be described later) such as multilines, varietal mixtures, broad-scale resistance, slow rusting, and geographic placement of varieties are being tested as methods to reduce the risk of disease epidemics. Efforts also are continuing to develop materials with additional drought, cold, and heat tolerance, as well as greater tolerance to aluminum and other minor element toxicities. Although the primary research thrust will continue to be plant breeding, an increasing emphasis is being placed on procedures to orient production agronomy research and on general production-related issues, particularly in the regional programs.

DISEASE RESISTANCE

The fungi that cause rust diseases—the most serious diseases of wheat—are obligate parasites that are genetically highly variable and unstable. They survive by changing their makeup so that they are able to attack new sources of resistance constantly bred into the small grains species. CIMMYT attempts to identify and develop cultivars with genetic protection against a broad spectrum of virulences through wide geographic testing. Varieties which show resistance in many locations can be considered to have a broad spectrum of resistance against many forms of the organism. Once identified, these varieties are used heavily in future crosses in order to continuously infiltrate into the general germ plasm base higher concentrations of genes for disease resistance. However, given the somewhat ephemeral nature of resistance, dynamic breeding programs are the only practical protection against severe crop losses that may result from these ever-changing pathogens.

Rust Resistance—Today, suitable high yielding wheat varieties that have good and stable resistance to stem rust and to stripe rust have been developed for most production areas. The situation at present is more precarious in the case of leaf rust, even though the level of resistance is high at the time of release. High yielding wheat varieties developed with combined stem and leaf rust resistance sometimes have succumbed to new races of leaf rust within three to four years after release in some areas. Leaf rust, when it becomes endemic, can cut average yields 10-40 per cent over large production areas in a relatively short time period. It can be serious in the wheat belt of the Indian sub-continent, and to a lesser extent in the Mideast and parts of North Africa.

Leaf Rust—Although CIMMYT has a great many materials with good leaf rust resistance, its efforts to date to bring together in a single variety sufficiently large numbers of genes to provide stable and long-term resistance have not been fully successful. It is considered that with continued selection pressure through testing populations to all variations of the pathogen, useful genes will be pyramided and longer term stability will be achieved. Concepts such as slow-rusting (e.g. when plants do become infected but at a very slow pace) are also being studied as a way to build resistance. CIMMYT expects that during the 1980's, a stability level comparable to that for stripe and stem rust will be achieved.

Each year CIMMYT receives collections of wild wheat species and wheat relatives and these are screened for genes for additional leaf rust resistance and other characteristics which may be incorporated into high yielding bread wheat varieties. In addition the spring x winter crossing program and the wide cross program (both to be described in greater detail later) are attempting to introduce new genes for disease resistance into spring bread wheats.

Along another line of defense, the concept of mutiline varieties, varietal mixtures, strategic geographic placement of varieties, and regional disease surveillance systems are being developed. (Such approaches are useful for all four crops and are described later in the report.)

Stem Rust—In general, CIMMYT materials have mitigated the threat of stem rust in those production areas planted with improved varieties. CIMMYT's bread wheat germ plasm has a very high level of resistance. Durum wheat, on the other hand, has less stem rust resistance. CIMMYT is planning a collaborative research project on durums with Ethiopia, where very virulent forms of stem rust exist allowing for good selection pressure, to develop higher levels of resistance. Triticale has good stem rust resistance, while barley generally escapes this disease because of its early maturity characteristics. The Kenyan National Wheat Program has developed a stem rust parental collection of resistant materials which is distributed via CIMMYT to several African, Mideast, Asian and South American countries for use in crossing programs to enhance still further resistance to this disease.

Still there are areas, principally in parts of India, and countries of East and North Africa, where stem rust susceptible varieties are being grown. Additional emphasis by national programs to introduce resistant varieties can now largely control this disease problem.

Stripe Rust—Considerable resistance to stripe rust exists in CIMMYT's wheat and triticale germ plasm. Barley, however, is still very susceptible to this rust disease. The threat of stripe rust is greatest at the higher elevations (with rainfall above 600mm) in India and Pakistan, the Mideast, the Mediterranean Basin, Western and Eastern Europe, China, and the Andean countries of South America. Stripe rust can cause up to 30—40 per cent loss in yield, and in severe cases total destruction. At present, barley production in the Andean region is the most seriously affected.

CIMMYT's regional programs in East Africa and the Andean region, in cooperation with the International Plant Protection Center in the Netherlands are exchanging resistant wheat, triticale and barley germ plasm for testing in both regions to develop more resistant lines. Selection for resistance in these very severe infection areas provides material for crossing in national programs worldwide. Although a considerable number of resistant varieties have been released by national programs, more resistant materials are expected to be developed and released during the 1980's.

CIMMYT is assisted in screening to particular races by the Rust Laboratories of the United States, Canada and Australia. These centers test the resistance of CIMMYT materials to the collections of rusts maintained by them.

Septoria Resistance—Septoria often is found in the same cool conditions (usually with rainfall above 700 mm) where stripe rust is a problem. These areas include countries of the Mediterranean Basin, Western Europe, the Rift Valley of East Africa, the Southern Cone of South America, and more recently in South Australia. It commonly occurs where rains and cloud cover are persistent for extended periods of time.

Bread and durum wheats are much more susceptible to Septoria than barley or triticale, In serious disease situations, 30 per cent or greater yield reductions can occur. Originally, CIMMYT wheat materials had little resistance to Septoria. After encountering serious Septoria epidemics in North Africa in the late 1960's, CIMMYT began a concerted effort to increase the resistance in its wheat germ plasm to Septoria through large-scale crossings. Since then, substantial progress has been made. Each year, CIMMYT distributes the International Septoria Observation Nursery (ISEPTON) to concerned countries. Regional nurseries also are screened for Septoria resistance. In addition, CIMMYT scientists are collaborating with national programs in Ethiopia, Kenya and Israel on this problem. Currently, through a Dutch supported program and in collaboration with CIMMYT, Israel is conducting basic screening to develop greater resistance to Septoria in its different forms. CIMMYT will place increasing attention on the problems of Septoria during the 1980's.

Helminthosporium Resistance—The different species of the fungal organism, Helminthosporium, can do considerable yield damage to wheat, barley and triticale. This disease is particularly serious in Eastern India, Bangladesh, parts of East Africa and in many warm tropical countries. CIMMYT expects to step up its research activity on Helminthosporium during the 1980's, with particular emphasis on races that occur in the tropical and humid regions of the developing world. In addition to the Helminthosporium Observation Nursery, already distributed to interested collaborators, CIMMYT expects to strengthen its collaborative research ties with certain affected countries in Asia and Africa to work on this disease problem.

Added Resistance to Less Serious Diseases—Additional collaborative research projects on other diseases are anticipated with selected national programs located in particular "hot spot" areas. Staff pathologists assigned to regional programs will be the primary CIMMYT research contacts in these collaborative research projects with back-up support supplied by the CIMMYT staff based in Mexico or in other regional programs. As the CIMMYT network of regional programs evolves over the next five years a much stronger capability will exist for monitoring and controlling diseases.

Tentatively, a coordinated research effort has been planned on barley yellow dwarf virus which is a problem of barley and wheat in the Americas. Research on *Rhyncosporium,* a problem on barley all over the world, is planned with Ethiopia where the disease is particularly serious. Research on *Fusarium* head scab, a problem with durum wheat in cool climates where a maize/wheat rotation is followed, is already underway with Argentina and Brazil.

OTHER MEASURES OF DISEASE CONTROL

Multiline Varieties—One problem with conventional pure-line wheat varieties (such as varieties based on CIMMYT bread wheat cross 8156 which were earlier grown on up to 20 million hectares) or any other self-pollinated crop species, is that all the individual plants of the variety have the same genetic make-up. Therefore, when a new variety with leaf rust resistance, for example, is released to farmers, all plants are resistant to the prevalent races of the pathogen that are then present in the region where it is to be grown. Sooner or later, when a mutant race of the rust pathogen appears that is virulent on the variety, the stage is set for the rapid build-up and spread of this new race. Since all plants of the variety are identical, and therefore, susceptible, an epidemic soon spreads with corresponding losses in production.

One promising approach to reduce the threat of disease attack on pure-line varieties is the development and use of multiline varieties. In elaborating a multiline variety, a series of lines (4 to 10 or more) are developed which are phenotypically similar (look alike). Each line, however, carries different complements of genes for rust resistance. These are then mixed mechanically to form a multiline variety. When a new race appears, it is highly probable that its virulence factor will have the ability to attack only one or two of the component lines in the multiline, while the others remain resistant. Consequently, the infection spreads very slowly, and is unable to incite an epidemic in such a diverse population.

Unfortunately, seed companies find multiline varieties more difficult to produce than pure-line varieties. Seed certification agencies also face difficulties in determining whether a variety is impure or whether it is a standard multiline mixture. Also, to make multiline development worthwhile, CIMMYT believes that only a widely used, widely adapted variety should be selected in which to develop the multiline, if the cost of development is to be justified. Another problem is that the yield potential cannot be expected to be much greater than that of the pure-line variety from which it was derived. The utility of the multiline has shown its advantage in oats, although more widespread adoption in other small grains is being hindered by seed certification laws and profit considerations in seed production.

Multilines are currently being introduced in India into the extremely large areas now planted to Kalyansona and Sonalika. CIMMYT in the 1980's will continue as part of its program to develop component lines for widely used varieties and will continue to encourage their use in indicated countries.

Varietal Mixtures—A slight variant to the multiline is the varietal mixture. In some cases (e.g. Kenya) this involves growing several different varieties on each farm in separate fields as a hedge against failure of any one variety. A second type being extensively studied in Western Europe is to mechanically mix 2 to 5 varieties, each different in appearance and agronomic characteristics, but similar in maturity. The use of varietal mixtures requires research—either by the farmer or the scientist—to work out the proper combination of varieties for maturity, height, grain type, etc. However, the principle of such mixtures can add yield dependability to the farmer's crop.

CIMMYT will watch the experiments with mechanical mixtures of varieties with interest and may expand its own research work in this area.

Strategic Geographical Placement—Another approach which has proven effective to contain threat of disease attack involves the strategic geographic placement of varieties. This entails placing varieties with resistance to a particular disease next to areas identified as the source of origin for a disease outbreak. In this system, only those varieties with adequate resistance are allowed by law to be planted in disease-source areas. In this way, initial inoculum is held in check and its spread is either controlled or effectively slowed until late in the life of the susceptible variety when little or no damage is done.

India has used this system effectively to contain endemic rust outbreaks originating in the north and south of the country. This approach, however, requires a good knowledge of disease epidemiology to be used effectively. As regional disease surveillance system continue to develop, this strategy may become an increasingly important disease control mechanism.

INCREASING INSECT RESISTANCE

In general insects are not a serious problem in most small grain producing areas. Where insect problem do exist (e.g. sawfly in the Mideast, hessian fly in North Africa, sunn pest in Turkey), CIMMYT will establish limited collaborative research projects with the appropriate research institutes as needed and incorporate resistance in its germ plasm for affected areas. Regional staff will coordinate CIMMYT's activities on these research problems.

TOLERANCE TO AGRO-CLIMATIC STRESSES

In determining priorities for research on problem production environments, CIMMYT scientists are mindful that maximum grain yields per hectare are produced when the variety with the highest genetic potential for yield is grown in an environment that is optimal for the crop. CIMMYT has always followed the policy of providing germ plasm which has the capability of response to good environments. Through the system of international cooperation with national programs, this highly responsive germ plasm is grown under varying conditions of moisture and other agroclimatic stresses. From this group of highly responsive materials, national collaborators select those lines which are most responsive to local conditions. In many instances, these production conditions are considerably less than ideal. Therefore, the superior lines which are selected that have demonstrated a capacity to perform well in poor environments, have already a built-in ability to respond to any yearly variations which improve the crop condition. This policy, through experience, has shown its validity as varieties continue to be released which outyield local types, even in the driest areas. At the same time, CIMMYT is continually selecting for performance in difficult production environments in collaboration with national programs and re-incorporating genes for resistance to agroclimatic stresses into the background CIMMYT germ plasm. In the 1980's, CIMMYT will, with its strengthening regional capability, be able to monitor more closely these needs and develop even more stable varieties under poor environments.

Cold Tolerance—In the developing world, a number of countries grow part of their crop as winter wheats (Turkey, Iraq, Iran, Afghanistan, and parts of Pakistan, Algeria, Korea, China, Argentina and Chile). These areas require wheats which possess differing degrees of cold hardiness.

CIMMYT has been working with scientists at Oregon State University (OSU) and in Turkey to develop winter hardy bread wheats. Winter x spring crosses are also made in durums, barley and triticale. The program will continue during the 1980's but with emphasis on developing durum, barley and triticale materials with somewhat more winter hardiness for winter production areas. CIMMYT expects to increase its collaboration with Turkey, OSU, and ICARDA in this research area.

Heat Tolerance—Among CIMMYT wheat materials are some lines which yield better than most in such high temperature, dry areas as Sudan and Nigeria. Each year, CIMMYT germ plasm is tested in Sudan and in Upper Egypt for high yield performance. Cooperative research along this line also has been initiated with India. In certain of these countries, low yields are often reported. In part, the lower yields are associated with a shorter growing season. More often, however, the low yields are due to the practice of late seeding which shortens the already short production season. CIMMYT hopes to increase work in this research area during the 1980's. The newly established North-West Africa regional program will be primarily involved in helping to select the most resistant materials. These will be crossed in Mexico to high yielding types and supplied for subsequent screening cycles in Sudan, Nigeria, other countries of West Africa, and India. Again, as in other sub-programs, selected materials will be crossed back into CIMMYT materials to incorporate these genes into the general germ plasm base.

RAISING YIELD POTENTIAL

Prior to the introduction of the genes for dwarfness into CIMMYT materials during the 1960's, the best wheat varieties rarely yielded above 4.5 metric tons per hectare. The improved tall varieties faced a yield barrier because of their susceptibility to lodging when heavily fertilized. The new semidwarf wheat varieties were resistant to lodging and raised the yield potential to 8.5 to 9 metric tons per hectare under optimum growing conditions. There is also strong evidence that semidwarfs carry genes for high grain production efficiency, *per se.*

Since the first release of these semidwarf varieties by national programs some 15 years, ago, the yield potential of new varieties has increased at a much slower pace. While CIMMYT believes that further increases in maximum genetic yield potential are possible, this objective is not given a major research priority since experimental plot yields already far exceed farmer yields in virtually every developing country. CIMMYT scientists, however, do see signs through spring x winter crosses and larger, more fertile heads, for an additional 1 to 2 tons per hectare in the varieties available in the early 1980's.

In durum wheat, triticale and barley, CIMMYT believes further yield improvements during the 1980's will continue to be realized, with durum wheats and triticales possibly surpassing the maximum yield potential of bread wheat. In particular, triticale has shown greater dry matter production than wheat, and further partioning to grain (versus straw) should push yields higher.

Spring x Winter Crosses—In search of higher and more stable yielding wheat materials, CIMMYT began in the early 1970's to cross spring and winter wheat varieties (both are grown in the developing world). From the beginning, this project has had the collaboration of scientists at Oregon State University and Turkey's National Wheat Program. CIMMYT scientists have concentrated more on the spring wheat side of the project and our collaborators on the winter wheat side.

CIMMYT considers that the spring wheats can be improved by adding genes from winter types for drought resistance, higher yield potential, a wider range of maturity, and greater resistance to Septoria, stripe rust and root diseases. Winter wheats can be improved through adding genes from spring types for greater rust resistance, higher yield potential (through the use of the semidwarf habit, greater fertility and larger heads) and wider maturity ranges (particularly earliness). Today, spring wheats with winter wheat genes are yielding 1 to 2 tons more per hectare than the best lines developed purely from spring x spring crosses. CIMMYT intends to continue and expand this collaborative research program during the 1980's. ICARDA scientists also expect to become more directly involved in this research work.

SPECIAL ISSUES

PROBLEM SOILS

Vast areas exist in South America and Africa with laterite soils characterized by low pH, high free aluminum and iron levels and a high phosphorus fixing tendency. Small grains are being produced in these areas, but with very low average yields. Given the increasing amounts of foreign exchange going to pay for imports of wheat flour, many developing countries are showing considerable interest in expanding small grain production (and increasing productivity) in non-traditional areas. In other traditional small grain producing areas, the soils are being degraded, with salinization one of the most serious problems.

CIMMYT scientists are following several research strategies related to these problems. One approach is to use wide crosses to develop varieties (or crops such as triticale) that have enhanced tolerance to some soil problems. For example, triticale has demonstrated that it can outproduce wheat 2 to 1 in certain acid soil environments. Another approach is to search for genetic variation within related species for plant types that exhibit additional tolerance to soil problems and then to incorporate this tolerance into higher yielding materials.

CIMMYT is involved with Brazil in a program to develop high yielding wheat varieties for the aluminum toxic, acid soils of the "campos cerrados" found in southern Brazil. (Similar soil conditions are also found in East Africa.) In this project, CIMMYT's high yielding semidwarf materials are being crossed with tall, low-yielding, agronomically poor Brazilian types that have the greatest known tolerance in wheat to aluminum toxicity. Through a program of shuttle breeding, CIMMYT and several Brazilian research organizations are developing improved materials at an accelerated pace by planting screening nurseries alternately in Brazil and Mexico in the same year. This has allowed selection for tolerance to aluminum toxicity in one cycle and for superior agronomic types in the next. This shuttle breeding approach will be continued in the 1980's. CIMMYT is also using a rapid laboratory screening technique developed by Washington State University, USA, to screen large segregating populations for resistance.

Salinity and alkalinity are other serious soil problems. However, CIMMYT considers these to be mainly engineering problems. A small amount of research with wide crosses is being attempted to see whether a measure of salinity tolerance can be transferred to wheat from its relatives among the grass family or from barley.

Plant Nutrients—Since minor elements appear to be limiting yields in substantial areas of the world, CIMMYT is attempting to assemble a series of crop plants which are good indicators of minor element deficiencies. If successful, such plant indicator sets will be distributed as international trials for testing in a series of locations.

WHEATS FOR TROPICAL AREAS

CIMMYT receives a considerable number of requests for seed from countries which have humid tropical production environments. These countries seek to grow wheat during their coolest season of the year. Disease problems (Helminthosporium and a variety of root rots) are particularly serious in these hot areas.

Although CIMMYT believes that small grains basically are best suited to the more temperate areas of the developing world, it has been involved, over the past several years, in collecting germ plasm with all known sources of resistance to *Helminthosporium sativum* and various foot rots. This material has been used in crosses in an attempt to produce resistant varieties for tropical areas. Thus far, the best materials have only shown a moderate tolerance to these diseases. CIMMYT is trying to pyramid some of this tolerance to see if better levels can be achieved. Further, CIMMYT is searching through different resistant grasses to see if genes for resistance can be transferred to wheat through wide crosses. This work will continue during the 1980's with somewhat greater emphasis than in the past. CIMMYT expects to establish shuttle breeding collaborative research projects with India, Nepal, Bangladesh and Zambia.

WIDE CROSSES

CIMMYT's first major involvement in wide crosses was with triticale, a hybrid of wheat and rye. This new crop offers tremendous promise for increasing cereal production in many areas of the world. In more recent years, crosses of bread wheat and durum wheat also have been made to transfer disease resistance, and other characters from one species to another. More recently, in collaboration with Kansas State University, CIMMYT has made crosses between wheat and barley; wheat and *Agropyron*; and wheat and *Elymus*. CIMMYT's principal aim is not to develop new crops, such as triticale, but to transfer genes into each of (or among) the four crops for greater disease resistance, tolerance to environmental extremes and higher protein quality. To date, problems have been encountered in doubling the chromosomes in certain crosses. At best, only partial fertility is achieved in these hybrids, although often they will cross successfully back to the crop species. Starting in late 1979, CIMMYT contracted the services of an experienced cytologist to assist in the wide cross work, and work will be expanded considerably during the 1980's. This increased activity is expected to provide very useful and directly applied results, particularly in locating genes for disease resistance where resistance is still unstable or deficient.

SPECIAL GERM PLASM DEVELOPMENT

In CIMMYT's conventional breeding programs, experimental lines are evaluated simultaneously for many different desirable traits. Lines which carry a particular character useful to the breeder, but intermixed with undesirable ones, are usually rejected in the conventional program. In order to capitalize on potentially valuable germ plasm, CIMMYT attempts to transfer useful genes into a good agronomic background. The resultant lines are then reintroduced as parents within the conventional breeding program.

In addition to the efforts to increase yielding ability of bread wheat through spring x winter crosses, CIMMYT is also continuing its efforts to increase the head size and spikelet fertility of bread wheats. Normally, as the number of grains per head increases, the number of tillers per plant decreases. CIMMYT scientists are attempting to alter this apparent inverse correlation by producing larger heads with more spikelet fertility than found in the present high yielding, widely adapted varieties. Progress has been achieved and work will continue during the 1980's. Other sub-programs are looking at protein levels, earliness, and stronger or shorter straw.

NUTRITIONAL QUALITY

Wheat grain ordinarily contains 10-14 per cent protein; barley grain, 8-9 per cent protein; and triticale grain, 12-14 per cent protein. Levels of lysine, a key limiting amino acid for human utilization of available protein, vary considerably in these crops. Triticale grain has an average of 3.6-3.8 per cent lysine; wheat has 2.7-2.9 per cent; and barley as high as 5.0 per cent lysine in the protein where a specific gene is present. CIMMYT is carrying out research in barley and triticale to maintain high lysine levels in the grain of improved lines. In addition, wide-cross research is being pursued to see if the genes available in barley for improved nutritional quality can be transferred to wheat. Using this strategy, it is hoped that higher quality protein can be established in wheat.

PROGRAMS FOR STAFF DEVELOPMENT

The second major dimension of CIMMYT's total program is its efforts to strengthen national programs. These efforts take various forms, including many different problem-oriented and practical training programs.

CIMMYT's in-service training programs are a major Center activity—some say the most important activity. Through these programs, over a thousand young scientists have come to Mexico. Today, many of these former trainees hold important positions in their respective country's research and production systems. Some have also pursued higher postgraduate degrees. Most continue to work in fields in which their training at CIMMYT is proving useful. CIMMYT places a high priority on the continuation of current training program levels.

CIMMYT offers several kinds of training and educational assistance to collaborating national programs.

—In-service training: generally 5 or 6 months residence in Mexico

—Degree training in cooperation with universities;

—Predoctoral fellows: 12 to 18 months in Mexico to do their thesis research;

—Postdoctoral fellows: 2-years service within CIMMYT's program;

—Visiting and associate scientist fellowships.

In all cases, the emphasis is on developing practical research skills through "hands-on" experience working side by side with CIMMYT staff members.

MAIZE TRAINING

CIMMYT expects to continue in the 1980's with its established maize training philosophy. In-service training is offered in production agronomy, crop improvement, laboratory techniques and experiment station management. Additional programs will be added in disease and insect resistance research techniques. The pre- and postdoctoral programs will stay at about 1980 levels (6 positions). Expanded visiting and associate scientist fellowships will be offered to mid-career national collaborators. CIMMYT also expects its training officers will increase their consultation to national programs on the organization of national training strategies for continuing staff development.

WHEAT TRAINING

CIMMYT intends to continue wheat in-service training programs at about 1980 levels. Program offerings include production agronomy (rainfed and irrigated), breeding, pathology, cereal technology, experiment station management and production economics. More trainees will be accepted from smaller or less traditional wheat-producing countries. The number of visiting and associate scientist fellowships for national collaborators will be increased. Training program staff will support national program efforts to organize production training programs. Although the absolute levels (6–8 positions) in the postdoctoral program will not increase appreciably, added emphasis will be placed on training agronomists.

ECONOMICS TRAINING

Staff economists work closely with the in-service production training program offered by the maize and wheat program each year. These in-service trainees spend about 20 per cent of their time learning to conduct surveys to ascertain the production circumstances of farmers and to plan subsequent production research activities. They also learn how to translate agronomic research data into economic recommendations to farmers.

In addition to the economics component in the in-service production training courses, the economics staff instituted in 1979 a three-months training program (held twice each year) for national collaborating economists which focuses on the procedures for conducting production-oriented research. Both training activities will continue during the 1980's.

PROCEDURES FOR CONDUCTING RESEARCH

During CIMMYT's research work in crop improvement and production, *per se*, it develops procedures and techniques of use to CIMMYT scientists and to national collaborators. These procedures emerge as bi-products of the Center's efforts to expedite and improve the efficiency of its own work. CIMMYT will continue to adapt and improve its procedures and to make the products of its experience available to national collaborators.

CROP IMPROVEMENT

Along with the breeding techniques described earlier in this report—those relating to the population improvement, to multi-site selection, to the work on quality protein maize, and to the assessment of large numbers of experimental materials under diverse climatic circumstances—CIMMYT's plant improvement work has led to other procedures of interest to national programs. One of these relates to the work on insect resistance in maize. In another dimension are the simple and efficient experiment station implements for laying out uniform research trials and for managing plots. In still another dimension are the research techniques developed in CIMMYT's laboratories for rapidly assessing very large numbers of samples of grain for protein, and milling and baking qualities. CIMMYT expects to see continued improvements in these and related procedures during the 1980's.

CROP MANAGEMENT

CIMMYT has long advocated off-station testing and demonstration as an integral part of production research activities and stresses the principles of on-farm testing in its training programs. Because experiment stations often are not representative of the circumstances of most farmers, on-farm research becomes important in providing information needed to develop appropriate recommendations. In this situation, on-farm research and experiment station research must be closely integrated with well-developed mechanisms for feed-back, and with both seen as integral parts of a total research system.

The Center's biological and economics staff have made a major effort to develop procedures to orient research aimed at framing recommendations. Two classes of on-farm research are involved. The first aims at ascertaining the natural and economic circumstances of representative farmers and the second focuses on on-farm experimentation departing from those circumstances. CIMMYT's concern is that the procedures be efficient in the sense of yielding the information required in an expeditious manner. The procedures feature close collaboration between biological scientists and economists in all phases of the work, from ascertaining the circumstances of representative farmers through on-farm experimentation and the formulation of recommendations.

While serving as a source of information for developing "best bet" recommendations for the near term, on-farm research can also provide evidence on what is biologically feasible to serve as motivating evidence—for policy makers and farmers—on the potential benefits from different production practices. In the longer run, policy makers can then modify policies so as to encourage desired changes in technologies. Meanwhile, in the near term, recommendations are based on what appears to offer an economical return, given the milieu of representative farmers.

Several national programs are now emphasizing this approach in organizing research for near-term recommendations. CIMMYT is synthesizing the accumulating experiences. Work will continue during the early 1980's, but at a decreasing pace as the utility of the approach is demostrated to the satisfaction of national programs.

POLICY RESEARCH

Policies which impinge on agriculture sometimes impede rather than facilitate the development and diffusion of improved technologies, often because the links between policy and the biological processes underway in agriculture are little understood. CIMMYT believes that a more precise understanding of these links would often lead to policies which would promote greater production. Work is underway to develop procedures which will encourage that kind of understanding. Special project funding now supports research aimed at relating proximate causes of low yields, evidenced in on-farm trials, to farmer responses to perceived natural and economic circumstances, and then to the policies which have shaped those circumstances. From this and similar efforts CIMMYT expects to forge procedures which provide useful information and analysis in an expeditious way.

Again, the procedures are based on close collaboration between biological scientists and economists and they feature a farm and market point of departure. One result will be to bring biological scientists and policy makers together on common problems. These procedures aim to provide policy makers with useful estimates of potential benefits of alternative public policies. Work on these procedures will receive increasing support by CIMMYT economists during the 1980's.

CONSULTATION ASSISTANCE

CIMMYT increasingly is asked by policy makers for advice on agricultural development issues. In general, CIMMYT staff offers policy advice in two important areas; the organization of agricultural research systems and on production constraints. To better respond to these policy-related questions, CIMMYT has been expanding its production-oriented policy research and technical assistance capabilities.

SEED PRODUCTION

In many developing countries national research services have developed improved varieties and agronomic recommendations of proven high yielding ability. Yet constraints still remain that effectively limit the adoption and regular use of these higher yielding technologies. One frequent problem lies in national seed production and distribution systems. If a country's agricultural productive capacity is to be realized, it is necessary to establish an effective method of providing good quality seed to farmers. CIMMYT will continue to support the efforts of collaborators to establish effective seed production systems. CIMMYT is aware of the seed production research and training program recently established at CIAT and hopes that this program can provide training opportunities to collaborators from national programs in seed production for all important food crops.

OTHER PRODUCTION CONSTRAINTS

Seed is only one of the number of essential inputs required by farmers to achieve greater productivity. In addition, farmers must have the right type of fertilizer on their farms before critical production periods. Herbicides and fungicides also are often needed. So is traction power—animal or mechanical. All of these elements, in varying proportions, must be available and at economic prices if the productivity of low-yielding farmlands is to be improved appreciably.

The growing problems of energy costs and scarcity are having an extremely serious impact on national efforts to strengthen agricultural research, extension and production in the developing world. Many developing countries are in difficult economic circumstances and they are using more and more of their limited foreign exchange on energy-related purchases.

CIMMYT regional and senior scientific staff are receiving more requests from public officials in developing countries for advice on issues related to maize and wheat research and production. The relative priority assigned to these consultation activities during the 1980's will be very much dependent on the success achieved during this period in increasing world food production. If agricultural growth rates fall considerably below "minimum" trend projections, CIMMYT staff may be compelled to spend considerably more time consulting with governments on ways to accelerate agricultural development in the developing world than otherwise.

INFORMATION

Among the IARC's, CIMMYT devotes a relatively small per cent of its total budget to publications and the preparation of audio-visual presentations and other types of training materials. Rather, it places a greater emphasis in its communications strategy on frequent CIMMYT staff contact and discussions with national collaborators, through the numerous mechanisms and relationships described throughout this chapter.

As the Center moves into the 1980's, it is reviewing its past policies on information services to determine whether more staff time should be devoted to information reporting and what implications different communications options would have on the Center's effectiveness. A consultant has been commisioned and his report will be completed by 1981.

CHAPTER FIVE

IMPLICATIONS FOR THE FUTURE

INTRODUCTION

The intent of this chapter is to synthesize the implications of the preceding chapter for some of CIMMYT's major activities. CIMMYT has chosen to project forward to 1986 the general structure of the institution and its activities. The timing of new activities is left to the biennial planning documents. This final chapter, then, looks at some general implications, points out some of the activities which will receive increased emphasis, details the general configuration of the Center in 1986, describes potential capital needs, and concludes with an estimate of 1986 staffing requirements.

GENERAL IMPLICATIONS

The center will continue to assign the highest priority to its efforts in germ plasm development and management. Agronomy will receive an increasing emphasis by both crops programs and more relative attention will be concentrated in regional activities (see Table 5).

MAIZE PROGRAM

The following paragraphs summarize the emphasis of the maize program during the period 1981-86. Crop improvement will continue to receive most of the program's energies.

CROP IMPROVEMENT

The maize program will continue to concentrate on population improvement and open-pollinated varieties through multi-trait selection and multilocational testing. National programs with sufficient technical expertise will be able to use these materials to develop hybrids. Expanded gene pools will be made available to national researchers with emphasis on materials which are widely adapted within the context of user needs defined by altitude, latitude, maturity, and grain type groups.

Within these broad classes a generalized effort will be made to reduce height and days to maturity while maintaining yield levels.

In general, disease problems will be of more concern to the program than insect problems. Even so, given the promise of work on developing insect resistance, this activity will receive more attention than in the past. With respect to the diseases, continuing attention will be given to leaf blights and to ear and stalk rots, all significant global problems (see Table I for details).

Special problems characterize some regions (see Table 1). Briefly, sub-Sahara Africa requires work on streak virus; the Andean region on ear rots along with special attention to plant efficiency; the Central American highlands on plant efficiency and maturity while the lowlands require work on stunt; the Middle East on stalk rots and late wilt; and South Asia on downy mildew compounded by incursions of late wilt. There is also evidence of downy mildew infiltration in Africa and northern South America. Work will be expanded on treating these problems.

Concentration on nutritional quality will be maintained, especially in stability of kernel hardness and in performance, with the continuing caveat that yields will not be sacrificed for nutritional quality. Where relevant, parallel efforts will go to the incorporation of greater disease and insect resistance. Projects to launch quality protein maize production in developing countries will be initiated in cooperation with relevant national programs during the period.

Work on wide crosses will be maintainded at roughly current levels as will work on special production problems like drought tolerance and aluminum toxicity.

MAIZE TRAINING

The maize program sees little change in its training activities over the period. There might be an increase in the collaboration of CIMMYT training officers with the training staff of selected national programs, but the extent of this increase rests on evidence of demand and opportunity from the side of the national programs. All in all, little change is expected in the funds and staff committed to training and the activities undertaken.

CONSULTATION

It is anticipated that this activity will demand roughly the same level of activity as in the past.

WHEAT PROGRAM

CIMMYT's wheat program work on small grains will continue to manifest its earlier hallmarks—wide adaptability, good yield potential, and strong disease resistance. The following paragraphs give the highlights for each of the four cereals handled by the program.

BREAD WHEAT

Marked progress has been made on yield plateaus in the past so emphasis has shifted to enhancing yield dependability. A series of challenges face plant breeders in the various regions of the world (see Table 2 for details). Some of these (e.g. the rusts) require continuous vigilance. For the rest, relatively more attention will be given to Septoria, Helminthosporium, Barley Yellow Dwarf, Fusarium, and root rot resistance in various regions. To increase plant capacity to accomodate stresses imposed by weather, more emphasis will be given to drought, cold, and heat tolerance as well as to adaptability to tropical conditions, given the increasing interest in wheats suitable for tropical areas. Soil problems amenable to breeding are evident impediments to yields in several areas and this issue will receive increased relative attention.

DURUM WHEAT

While durum yield plateaus have advanced notably there is still evident opportunity for additional increases. Diseases of most concern are Septoria, Fusarium and stem rust (for details see Table 3). Drought and cold tolerance will be given more attention. There is an increasing attention to grain quality as potential exporters see opportunities in European markets for durums suitable for pasta.

BARLEY

Yield plateaus and dependability are of roughly equal concern to barley breeders. In general the plant type is approaching suitable configurations although the grain type for hull-less barleys requires more attention. Earliness is another dimension to receive added attention. Diseases requiring additional emphasis are *Rhycosporium, Helminthosporium,* stripe rust, and Barley Yellow Dwarf virus in roughly that order (see Table 4 for details). Work on protein quality will be carried on at about current levels.

TRITICALE

Yield plateaus can be pushed to even higher levels as evidenced by triticales notable production of dry matter. One avenue being exploited is shifting the partitioning toward additional grain production. Good resistance to rusts and smuts are evident but this must be protected through careful monitoring as production areas expand. Losses to post-harvest sprouting will receive added attention as will resistance to Fusarium and leaf blight. Some areas need additional cold tolerance, e.g. Argentina in forage triticales and Algeria for grain types. (No table was prepared for diseases because to date, with few production areas, common diseases are not an evident problem.)

CROP MANAGEMENT

There will be a relative increase on the emphasis assigned to crop management, especially through the regional activities (see Table 5). Attention will focus on soil fertility, weed control, and water management. Beyond these, issues of special concern to individual regions will be emphasized in regional programs.

TRAINING

No changes are contemplated in the resources assigned to the wheat training program. Even so, it is expected that this activity will concentrate more of its efforts in collaboration with national program training staff on in-country training efforts.

CONSULTATION

It is anticipated that this activity will demand roughly the same level of effort as in the past but it is contemplated that scientific staff travel will be more selectively made as regional staff pinpoint areas of major concern based on their first-hand assessments of the problems.

ECONOMICS PROGRAM

In the recent past, the economics program has concentrated much of its effort on the formulation of procedures for integrating the circumstances of representative farmers into research aimed at framing recommendations. Emphasis has been given to collaborative research with biological scientists and a considerable part of the work has been with national programs. A second substantial commitment has been to training (see Table 5).

It is anticipated that work on procedures and on training will continue to occupy program efforts in 1981-86, but the mix of activities will vary from that currently featured. Most notable will be the shift in emphasis on procedures. Current efforts concentrate on collaborative procedures for ascertaining farmers circumstances to facilitate the formulation of appropriate recommendations. In the early 1980's, it is anticipated that less attention will be devoted to this theme and more importance will be given to a class of policy issues. In particular, more attention will be focused on issues that relate to research and technology development as instruments to achieve broader, macro-policy goals.

There is an evident need to foster discussion among policy makers, biological scientists, and economists on the orientation of agricultural research and on the formulation of technologies. More effective communication of ideas on what is desirable from the policy standpoint, what is feasible from the biological standpoint, and on what are the likely implications of alternative research thrusts will add significantly to the performance in research and policy. Again, departing from farm and market level circumstances, the focus will be on forging procedures for fomenting collaboration among biological scientists, policy makers, and economists.

In more general terms, the program will give more attention to the ways in which the relevance of alternative technologies are influenced by such considerations as food preferences and the responsiveness of local markets, by limitations on access to cash, by the availability of family labor, by the role of risk/security considerations, and by the overall stock of farm assets. Some of this research will be done through special projects.

Some added emphasis will be given to data and analysis, especially for collaborating national programs. The resources committed to training will be roughly at current levels. (See Table 5, Economics, for additional details.)

CAPITAL DEVELOPMENT NEEDS OF CIMMYT

The basic physical facilities at CIMMYT headquarters and experiment station were funded by the Rockefeller Foundation and constructed in 1970-71. The total cost of this investment was US$4.1 million. Inexpensive buildings have been added to the experiment stations from annual budgets as needed. This process is likely to continue. In 1973-74, twelve apartment units were constructed to accommodate postdoctoral fellows with families and in 1975-76, eight efficiency apartments were built for temporary accommodation of staff and single postdoctoral fellows. During 1980, sixteen apartment units will be added for visiting and associate scientists with funds provided on a special project basis by the Federal Republic of Germany. In 1980-81, a new wheat germ plasm storage and handling facility will be constructed from core restricted funds provided by the Government of Japan.

In projecting CIMMYT's long-range capital needs, three items which require larger than "normal" capital investments would add substantially to the utilization of current capacity and/or the effectiveness of CIMMYT's programs.

CIMMYT's current data processing section relies on computers purchased in 1975. While adequate for CIMMYT's perceived needs at that time, the machines are somewhat slow, lack flexibility and are complex to program compared to more "modern" computers. In 1979, CIMMYT retained a consulting firm, the Laboratory for Information Sciences in Agriculture (LISA), Colorado State University, to review current and likely future data processing needs and make recommendations on ways to strengthen, if needed, this section of CIMMYT's supporting services. Their report recommended the replacement in 1981 of the present computer and selected software to provide a system with greater speed, capacity and flexibility. The estimated cost of this change is $250,000.

CIMMYT's cafeteria was built as a part of the initial construction. Since that time the number of staff, trainees, postdoctoral fellows and visiting scientists using the facility has more than doubled. Even with staggered lunch hours, the facility is inadequate to meet current needs. Lack of storage space prevents quantity purchases and sanitary facilities are inadequate for the number of workers using the facility. Recently, a restaurant management consulting firm prepared a report which recommended substantial reorganization, remodeling and modernization. They estimated that $125,000 will be required for this purpose.

Increasingly CIMMYT is being asked to accept longer-term, more specialized trainees, visiting and associate scientists and graduate students conducting field research. It appears that there is a growing need for international workshops, seminars, and symposia. Adequate space and appropriate facilities have become a limiting factor in expanding these types of activities. A modest building with facilities for training and conference functions, plus office accommodations for training officers and longer-term trainees, would greatly add to CIMMYT's effectiveness in these areas. CIMMYT will assess the needs for such a facility over the next two years and, if its effectiveness is evident, the Center will then seek appropriate financing.

ESTIMATES OF 1986 STAFF REQUIREMENTS

The 1980 core assignments are juxtaposed with the planned 1986 assignments for the major activities (Table 5). As is evident in the table, virtually all changes occur in regional programs where the major increase is in crop management.

It is expected that there will be changes in special-project activities. Their character will depend largely on the emerging needs of national programs and CIMMYT's evolving demand for complementary basic research.

With certain minor exceptions, changes in core and special-project staff commitments will not themselves induce additional changes in CIMMYT international staff in supporting services. Virtually all of the contemplated additions to staff are in regional positions, where collaborating institutions provide needed support. Two additional senior staff support positions are envisioned at headquarters.

Table 1. Relative Emphasis[i/] on Various Problems in Maize Improvement for Selected Regions in 1981-86.

	R	LB	ER	SR	DM	SK	ST	LW	B	FAW
Africa (Sub-Sahara)	1	1	1	1	1	3			2	
Andean[ii/]	1	1	2	1					2	
Cen/S America[ii/] Highlands	1	1	2	1						
Lowlands	1	1	1	1	1		2			2
S America[ii/] (South Amazon)		1	1	1						
Middle East		1	1	1				2	2	
South Asia		1	1	1	3			2	2	

Abbreviations

R = Rusts
LB = Leaf blights
ER = Ear rots
SR = Stalk rots

DM = Downey Mildew
SK = Streak virus
ST = Stunt
LW = Late wilt

B = Borers
FAW = Fall army worm

1 = A problem requiring vigilance.
2 = A problem which will receive added attention in 1981-86.
3 = A severe problem which will receive added attention 1981-86.
○ = Indicates a region in which special efforts for the entire integrated network will be made.
i = Problems and regions not necessarily listed in order of priority.
ii = Andean refers to highlands only
Cen/S America to area north of Amazon Basin
S America refers to area south of Amazon Basin.

Table 2. Relative Emphasis[1] on Various Priorities in Bread Wheat Improvement for Selected Regions in 1980-86.

	RUSTS SM	RUSTS SP	RUSTS LF	SEP	HEL	BYD	FUS	SMT	BNT	ROOT ROT	COLD	HEAT	TROP	DHT	ALUM
South Asia	2	1	2	0	2	0	0	2	1	1	1	1	1	1	1
Middle East	1	2	1	1	0	0	0	2	1	1	3	1	0	2	0
North-West Africa	1	1	1	2	0	1	1	1	0	1	1	2	1	2	1
Southern Cone	2	1	2	3	2	2	2	1	1	2	1	1	1	1	2
East Africa	3	1	2	1	2	0	0	1	0	1	0	1	0	1	2
Andean	1	2	1	2	1	2	0	1	1	1	0	0	1	1	1

0 = Not historical problem.
1 = A problem requiring continuing vigilance.
2 = A problem which will receive added attention in 1980-86.
3 = A severe problem which will receive added attention in 1980-86.
○ = Indicates a region in which special efforts for the entire integrated network will be made.
i = Problems are not necessarily listed in order of priority.

Abbreviations

SM = Stem Rust
SP = Stripe Rust
LF = Leaf Rust
SEP = Septoria
HEL = Helminthosporium
BYD = Barley Yellow Dwarf
FUS = Fusarium
SMT = Smut
BNT = Bunt
TROP = Wheats for Tropical Areas
DHT = Drought Tolerance
ALUM = Aluminum Toxicity

Table 3. Relative Emphasis in Various Priorities for Durum Wheat for Selected Regions in 1980-86*

	RUSTS												
	SM	SP	LF	SEP	HEL	BYD	FUS	ROOT ROT	COLD	HEAT	TROP	DHT	ALUM
South Asia	1	1	0	0	0	0	0	1	0	1	1	1	1
Middle East	1	1	0	1	0	0	1	1	2	0	0	2	0
North-West Africa	1	1	0	2	0	1	2	1	1	1	0	2	1
Southern Cone	0	1	0	1	0	1	2	1	1	0	0	1	0
East Africa	1	1	0	1	1	0	1	1	0	0	0	1	1
Andean	0	2	0	1	0	1	0	1	0	0	1	1	1

Abbreviations

SM = Stem Rust
SP = Stripe Rust
LF = Leaf Rust
SEP = Septoria
HEL = Helminthosporium
BYD = Barley Yellow Dwarf
FUS = Fusarium
SMT = Smut
BNT = Bunt
TROP = Wheats for Tropical Areas
DHT = Drought Tolerance
ALUM = Aluminum Toxicity

* See Table 2 for notes.
Powdery Mildew, Bunt, Smut have little impact on Durums in the regions where durums are currently grown.)

Table 4. Relative Emphasis in Various Priorities in Barley for Selected Regions in 1980-86.*

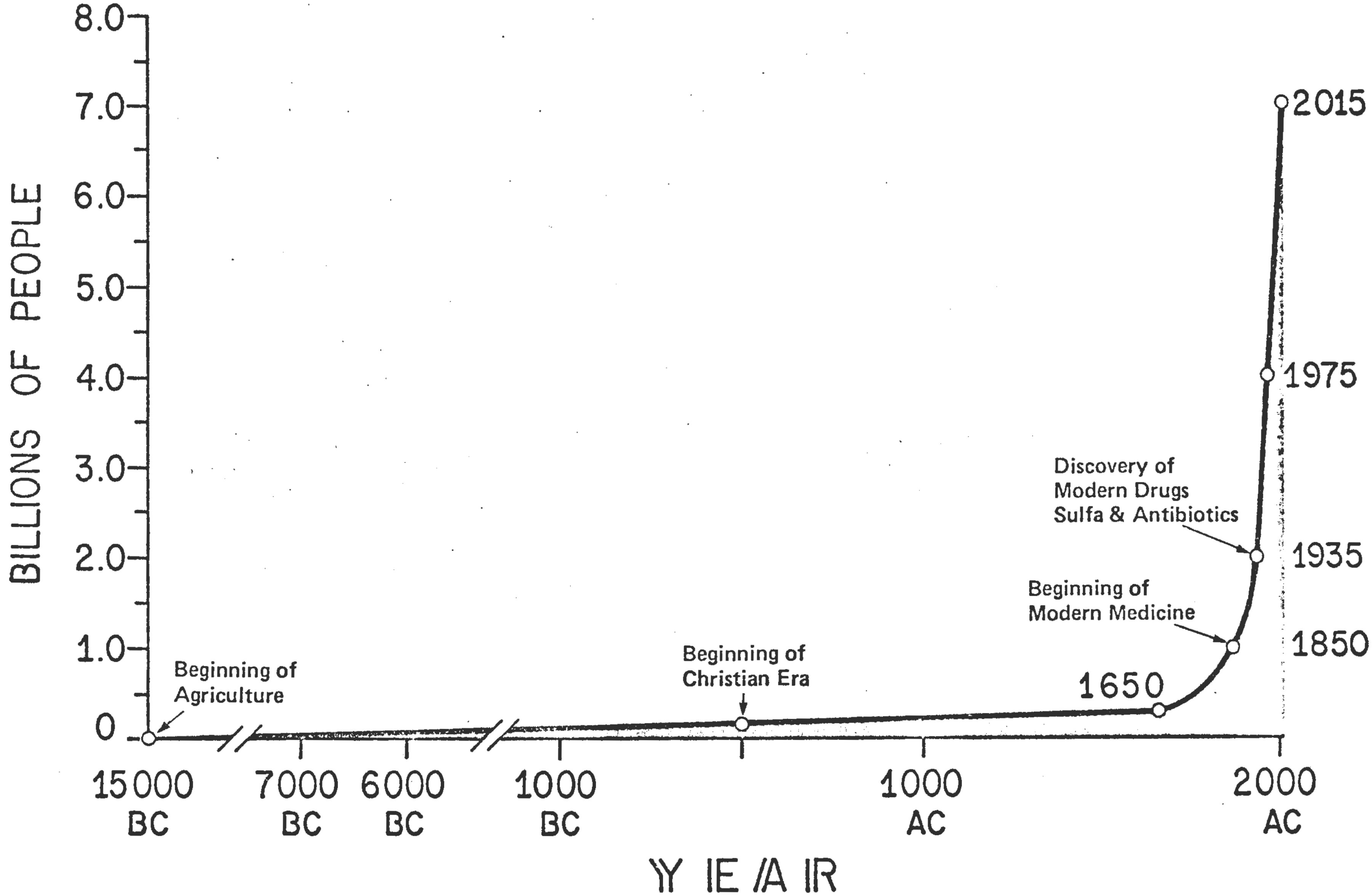
		RUST			BYD	RHY		SMT	COV	COLD		DHT
	SM	SP	LF	HEL		SP	PM		SMT		HEAT	
South Asia	1	1	0	1	0	1	0	1	1	0	0	1
Middle East	0	1	0	1	0	1	1	1	1	1	0	2
North-West Africa	0	0	0	2	1	1	1	1	1	1	1	2
Southern Cone	1	1	1	1	2	1	0	1	1	0	0	1
East Africa	1	1	1	1	0	2	1	1	1	0	0	2
Andean	0	2	1	1	2	1	1	1	1	0	0	1

Abbreviations

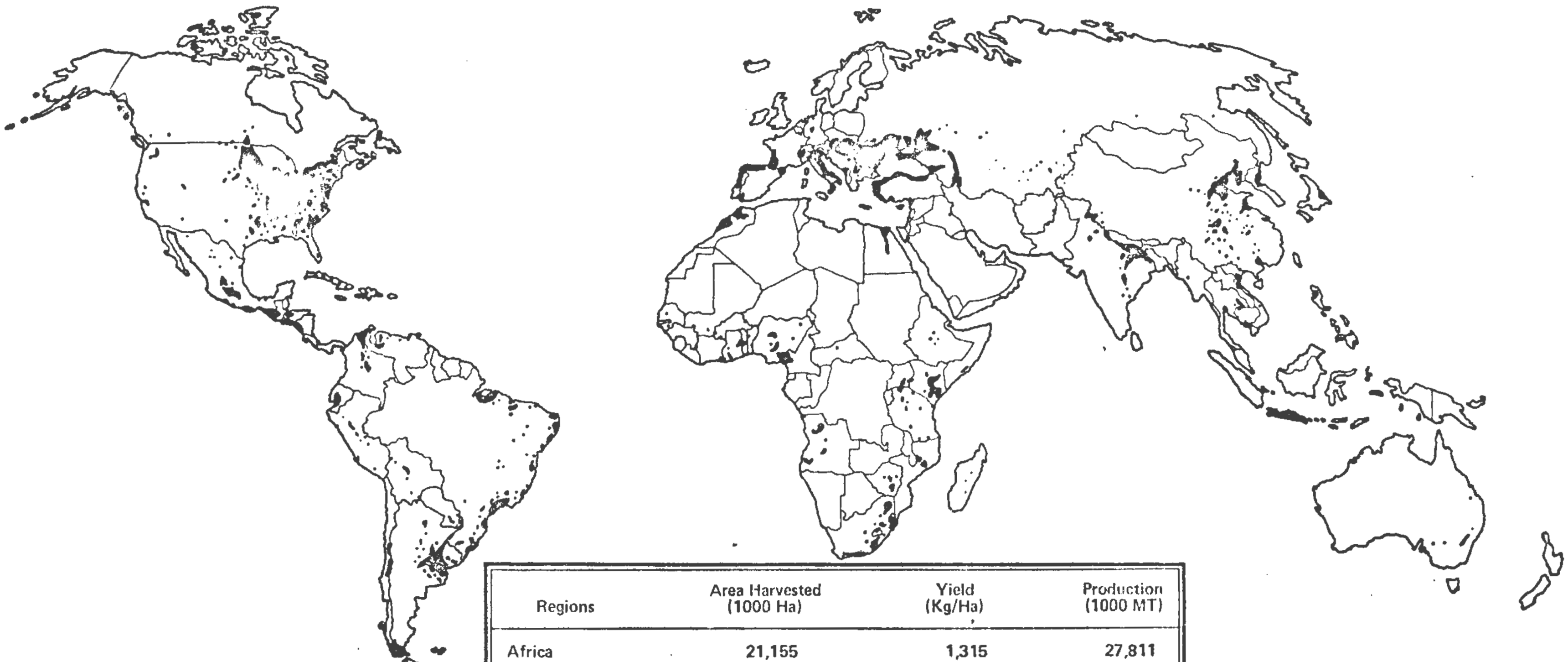
SM = Stem Rust
SP = Stripe Rust
LF = Leaf Rust
SEP = Septoria
HEL = Helminthosporium
BYD = Barley Yellow Dwarf
FUS = Fusarium
SMT = Smut
SMT COV = Smut, covered
BNT = Bunt
PM = Powdery Mildew
TROP = Wheats for Tropical Areas
DHT = Drought Tolerance
ALUM = Aluminum Toxicity
RHY = Rhyncosporium

* See Table 2 for notes.

WORLD POPULATION GROWTH



MAJOR AREAS OF MAIZE PRODUCTION



Regions	Area Harvested (1000 Ha)	Yield (Kg/Ha)	Production (1000 MT)
Africa	21,155	1,315	27,811
North and Central America	38,125	5,145	196,165
South America	16,330	1,639	26,759
Asia	27,906	1,951	54,446
Europe	11,638	4,161	48,422
Oceania	79	4,668	368
USSR	2,535	3,550	9,000
Developed, All	49,352	5,103	251,838
Developing, All	68,415	1,624	111,133

Source: 1978 FAO Production Yearbook

Table 5. International Staff Assignments for 1980 and 1986 (Projected) Core Staff Only

	1980	1986	Change
Maize			
Headquarters			
Improvement	13	13	
Training	3	3	
Regional			
Improvement	7	8	1
Agronomy	3	6	3
Direction	2	2	
Total	28	32	4
Wheat			
Headquarters			
Improvement	14	14	
Agronomy	3	2	–1
Training	3	3	
Regional			
Improvement	7	12	5
Agronomy	2	6	4
Direction	2	2	
Total	31	39	8
Economics			
Headquarters			
Procedures/ Data-Analysis	1	2	1
Training	1	1	
Regional			
Procedures/ Data-Analysis	3	4	1
Training	1	1	
Direction	1	1	
Total	7	9	2
Support Staff			
Research	10	11	1
Administration	6	7	1
Total	16	18	2
Grand Total	82	98	16