CIMMYT REVIEW 1982

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1982

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO 1982
Londres 40, Apartado Postal 6-641, 06600, México, D.F. México

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DIRECTOR GENERAL'S OVERVIEW

CIMMYT Review 1982 is intended to provide highlights of CIMMYT program activities during 1981 for the informed layman. It is complemented by technical maize and wheat improvement reports, more than a dozen international testing reports, and various other technical and informational bulletins published by CIMMYT each year.

In 1981, the number of collaborating countries and the interest of national scientists from the developing world in CIMMYT's germplasm and other services continued to grow. To respond to this growing demand, CIMMYT mapped out a plan for the 1980s which was designed to serve more effectively the program needs of our developing country clientele. This plan called for modest expansions, in real terms, in CIMMYT's human and financial resources during the 1980s. Sufficient funds, however, have not yet been made available to implement the workplan originally envisioned.

In 1981, funding shortfalls required CIMMYT to hold its international staffing to 80 percent of the level approved by the Board of Trustees. We were forced to defer the hiring of new staff and leave approved positions unfilled which became vacant through attrition. Plans for staffing regional programs and needed maintenance in our physical plant, now 12 years old, were also deferred. In an effort to keep our critically important training activities at planned levels, we also sought emergency special project funding to underwrite training fellowships.

Because prior investments were made in supporting CIMMYT's research development activities, we are able to report continuing benefit flows to agricultural producers and consumers in the developing countries and, indeed, the world. Globally, during the past two decades, the production of maize has increased at a rate slightly higher than the rate of population increase. In the case of wheat, the global figure exceeds the rate of population increase, providing slightly increased per capita supplies. A disproportionate share of this increase has been in the developing world,

where the rate of growth in production has been nearly twice the rate of population growth over the past 20 years.

In 1981, over 35 million hectares of wheat in developing countries (more than half of the total) were planted to high-yielding varieties, with CIMMYT germplasm in their parentage, and the added value of these production increases has conservatively been estimated to exceed 5 billion dollars per annum.

New, more specifically adapted wheat varieties with greater yield dependability are being released by national collaborators at an accelerated rate. And the new genetic materials currently emanating from CIMMYT's wheat improvement system are better suited for resource-poor, more difficult production environments.

CIMMYT's maize program, substantially reorganized in 1973-74, is now beginning to show significant results. During the past four years, some 22 countries have reported the release of 70 new higher-yielding varieties and hybrids containing CIMMYT's genetic material. These varieties, in general, are also more resistant to the important pests and pathogens of maize. As an adequate supply of high-quality seed becomes available, the impact of these new releases will be substantial.

We believe that the program activities and new initiatives described in this report are essential to the continued expansion of cereal production in the developing countries (and the world) during the remainder of this century. CIMMYT's future ability to continue effectively to respond to its mandate hinges on the restoration of current budget reductions, and modest expansions, in real terms, of the generous support that donor organizations have provided in the past. CIMMYT's growing financial crisis is also mirrored in many of the agricultural research budgets of our national collaborators. Unless the pay-offs, complexities, and cummulative nature of agricultural research are more fully understood by policy makers in developing countries and by the representatives of donor agencies that fund research in such organizations, sustained progress toward meeting future research requirements for expanded food production cannot be assured.

R.D. Havener

maize improvement

INTRODUCTION TO THE MAIZE PROGRAM

CIMMYT, with a global mandate to assist national maize programs throughout the developing world, emphasizes the improvement of maize populations for a wide range of production circumstances and consumer preferences. We endeavor to develop broadly-adapted materials with increased maximum genetic yield potential as well as enhanced stability of yield when grown under stress situations. Given the circumstances of the majority of farmers in the developing world and because of the weaknesses in the seed production and distribution systems in many collaborating countries, we emphasize open-pollinated varieties as the end product in CIMMYT's improvement work.

The advantages of high-yielding, open-pollinated varieties are several. From a breeding standpoint, the development of open-pollinated varieties requires less time than is the case with hybrids. Genetically more heterogeneous, open-pollinated varieties also offer more buffering capacity against the vagaries of climate. From a seed production standpoint, varieties are easier to multiply than hybrids. Also, since the seed of varieties can be saved from season-to-season, a lower volume of total seed production is needed to serve maize farmers in any given year.

Although CIMMYT emphasizes the development of open-pollinated varieties, our populations and pools are increasingly being used by countries interested in hybrid development. Indeed, various kinds of hybrids account for about 25 percent of the reported new releases by national programs.

For most maize-producing areas in the developing world, varieties capable of vastly improved yield levels as compared to traditional materials are now available. Additional work is still needed to improve the disease and insect resistance and tolerance to other environmental stresses of these materials. Earlier-maturing varieties with high and stable yields are also desired by farmers in many

areas. Such research is under way at CIMMYT and in collaborating national programs.

Despite the progress made over the last decade in maize improvement for the tropics and subtropics, significant obstacles to the delivery of improved technology to farmers still remain. Several key factors are needed for successful maize improvement and production programs. First, researchers must clearly understand the circumstances of farmers in areas targeted for research attention. This requires a strong production orientation within research (and extension) organizations. Without the means and mobility to interact with farmers on a continuing basis, it is difficult for scientists to keep their work properly focused. Continuity in research leadership, staffing, and funding is another critical factor for success; too often, this continuity is lacking.

Adequate seed production and distribution systems are also essential to any national campaign for increased maize production. Without a national infrastructure to produce and distribute the seed of improved varieties, the efforts of maize researchers to increase yields remain largely stymied. Finally, policies and agricultural development strategies are needed to stimulate increased production.

Despite growing funding shortfalls, we have endeavored to keep our in-service training programs strong, and can now count as alumni over 1,000 scientists (in-service trainees and visiting scientists) from more than 60 countries. We have also continued to strengthen our regional program network, a vital cornerstone in CIMMYT's strategy to serve its global clientele in the 1980s and beyond.

In the pages that follow, CIMMYT's maize program activities during 1981 are highlighted. We believe that we have an international program that is effectively supporting national research efforts to harness the tremendous and substantially untapped biological potential of maize as a food crop in the years ahead. As developing countries achieve higher income levels, in addition to direct food consumption, more maize will be devoted to the production of livestock products. We welcome the research challenges posed by this expanding demand.

E. W. Sprague

GERMPLASM DEVELOPMENT

The maize germplasm development and improvement strategy followed by CIMMYT begins in what we call the Back-Up Unit, whose staff is charged with the first stages of germplasm development for different types of maize needed to serve various of the world. The Back-Up Unit evaluates materials from around the world, maintains CIMMYT's maize germplasm bank (the largest in the world), and creates and improves gene pools classified on the basis of climatic adaptation, maturity characters, and grain type.

Based on these agroclimatic and maturity characteristics, as well as grain color (yellow-white) and type (flint-dent-floury), CIMMYT has assembled 33 gene pools to serve maize-growing areas around the world. Of these, two highland pools were added in 1981. One, pool 8, includes highland yellow semi-flint materials of late maturity. The other, pool 9, includes highland white dent materials of late maturity, and was assembled for African highland areas. At present, we have 12 gene pools for tropical lowland zones, 9 for tropical highland zones, 8 for subtropical zones, and 4 special pools for temperate zones.

Each of these gene pools is a mixture of genetically diverse germplasm drawn from many countries (but with some common characteristics), undergoing continuous recombination and improvement. New introductions are continuously added to these pools, and superior families are identified and transferred to CIMMYT's corresponding advanced maize populations, which are regularly distributed to national collaborators through the international maize testing program.

Improvement of pools

CIMMYT's gene pools are being improved using a modified half-sib (half-brother or half-sister) crossing and selection method. The size of each pool is maintained at approximately 500 families. Pools are grown twice a year at several locations

CIMMYT's maize gene pools

Gene pool	Abbreviation
Tropical Highland	
Pool 1—Early White Floury	H.E.W.FL.
Pool 2—Late White Floury	H.L.W.FL.
Pool 3—Early Yellow Floury	H.E.Y.FL.
Pool 4—Late Yellow Floury	H.L.Y.FL.
Pool 5—Late White Morocho (semi-flint)	H.L.W.Mor.
Pool 6—Early Yellow Morocho (semi-flint)	H.E.Y.Mor.
Pool 7—Late White Morocho (semi-flint)	H.L.W.Mor.
Pool 8—Late Yellow Morocho (semi-flint)	H.L.Y.Mor.
Pool 9—Late White Dent	H.L.W.D.
Tropical Lowland	
Pool 15—Early White Flint	T.E.W.F.
Pool 16—Early White Dent	T.E.W.D.
Pool 17—Early Yellow Dent	T.E.Y.D.
Pool 18—Early Yellow Flint	T.E.Y.F.
Pool 19—Early Yellow Dent	T.E.Y.D.
Pool 20—Intermediate White Dent	T.I.W.D.
Pool 21—Intermediate Yellow Flint	T.I.Y.F.
Pool 22—Intermediate Yellow Dent	T.I.Y.D.
Pool 23—Late White Flint	T.L.W.F.
Pool 24—Late White Dent	T.L.W.D.
Pool 25—Late Yellow Flint	T.L.Y.F.
Pool 26—Late Yellow Dent	T.L.Y.D.
Subtropical	
Pool 27—Early White Flint	Tm.E.W.F.
Pool 28—Early White Dent	Tm.E.W.D.
Pool 29—Early Yellow Flint	Tm.E.Y.F.
Pool 30—Early Yellow Dent	Tm.E.Y.D.
Pool 31—Intermediate White Flint	Tm.I.W.F.
Pool 32—Intermediate White Dent	Tm.I.W.D.
Pool 33—Intermediate Yellow Flint	Tm.I.Y.F.
Pool 34—Intermediate Yellow Dent	Tm.I.Y.D.
Special temperate pools	
Northern Temperate Region	NTR Pool
Intermediate Temperate Region	ITR Pool
Southern Temperate Region	STR Pool
CIMMYT—German Exotic Maize Gene Pool	—

in Mexico. Yield potential, height, maturity, lodging, husk cover, disease and insect reaction, and uniformity are taken into account at appropriate stages of plant development. The seed of ears from the best plants in superior families is used to reconstitute the pool for the next improvement cycle.

With the half-sib selection method, two cycles of improvement are completed each year. Two guidelines are fol-

CIMMYT has assembled a range of broad-based gene pools to serve the major maize-growing areas of the developing world. These pools are living collections of much of the genetic diversity found within the maize species.

lowed in this germplasm improvement scheme. First, to maintain as broad a genetic base as possible a low level of selection pressure is applied when improving the pools. Second, a provision is made for the systematic introduction of additional promising germplasm into each pool.

During 1981, several hundred new introductions, either drawn from the maize germplasm bank or provided by national collaborators, were evaluated in Mexico for agronomic attributes including maturity, height, yield potential, and reaction to certain diseases. Superior materials identified among these new introductions were then added to the appropriate gene pools.

Insect and disease resistance

Most of CIMMYT's pools have reached the stage of having agronomically acceptable plant types. In recent years, therefore, we have increased our efforts to improve the insect and disease resistance of these materials. These pools are artificially infested with insect larvae and/or artificially inoculated with disease-causing organisms that are endemic in areas where the pools are undergoing improvement and in relation to the principal pest problems in the areas where each pool is meant to serve.

In the tropical highland pools, selection is made for increasing resistance to earworms and ear rots. In the tropical lowland pools, selection is practiced for resistance to stalk and ear rots, fall armyworm, and sugarcane borers. In the subtropical pools, selection is practiced for resistance to ear and stalk rots, leaf blights and borers. In 1980 and 1981, several pools were tested to determine the progress achieved in developing disease and/or insect resistance. In some pools, increasing levels of resistance to certain insects and diseases were evident in the latest cycles of selection compared to earlier cycles of the pool.

Early maturity

Until recently, most of CIMMYT's improved germplasm had intermediate to late maturity characteristics. Over the last four years, the Back-Up Unit staff has made a special effort to develop more early-maturing germplasm with higher

yield potential and disease resistance. Selection for early-maturity is accomplished by identifying 1,500-2,000 of the earliest silking plants in each pool, and then retaining only those superior ears which are also relatively drier at harvest. The objective is to identify and retain the early-maturity genotypes with faster "grain-filling" and "drying-down" characteristics. As a result of this work, new groups of early-maturing materials are now flowing into Advanced Unit populations.

Highland maize pools

CIMMYT has formed nine gene pools to better serve the germplasm requirements of highland tropical areas. These pools mainly contain floury-type materials (large, soft kernel) and *morocho* types (semi flint, large kernel) of varying maturity ranges. The improvement of these highland materials is carried out using a "shuttle breeding" strategy. A CIMMYT maize breeder is stationed in Ecuador as part of a collaborative research project with INIAP, Ecuador's nacional agricultural research institute. The breeding cycle in Ecuador is used to improve the overall agronomic suitability and grain type of the different highland pools and to select for different maturity periods. The cycle in Mexico focuses on increasing the resistance of the Ecuadorian-selected materials to ear rots and earworms. Another important breeding objective in this research is to broaden the genetic base of floury materials, which until recently was very narrow.

Highland floury materials have traditionally had a very narrow genetic base, a fact that has retarded work to improve yield potential and other agronomic characters. Recently, we initiated an exploratory research program to incorporate high yielding temperate germplasm into our floury gene pools. This work is being carried out at CIMMYT's El Batan and Tlaltizapan stations.

Improved early maturing, floury maize varieties, with somewhat enhanced pest resistance, are beginning to enter into commercial production in the Andean highlands, particularly in Ecuador. Although some of these new early varieties do not yield more than traditional long-season maize varieties, they mature 40-60 days earlier, thus allowing the farmer the possibility of intensifying his annual production

by adding another crop such as a legume or potatoes, each year.

Special temperate gene pools

Breeders in temperate areas have become increasingly concerned about the narrow genetic base in maize materials used in that zone. CIMMYT, in order to broaden the genetic base of both temperate and tropical germplasm groups, began in 1978 to assemble several special gene pools. These pools allow CIMMYT scientists to introduce exotic germplasm into

A new research project is under way to develop temperate x highland floury germplasm. The objective is to broaden the narrow genetic base of highland floury materials through the introgression of high-yielding temperate germplasm.

temperate-based materials, which in turn serve as a mechanism to move genes from temperate materials into tropical lowland and highland germplasm. The result should benefit the breeding efforts of maize scientists in both developing and industrialized countries. Three pools have been formed which are adapted to different temperate zone regions. In addition, a special CIMMYT-German exotic temperate x tropical gene pool has also been formed in cooperation with scientists from the University of Hohenheim, West Germany.

Utilization of gene pools

CIMMYT's maize gene pools are fulfilling their function of providing useful genetic diversity in our population improvement program. Twice each year, these collections of genetically diverse maize materials are thoroughly recombined. Some offspring plants carry a higher number of desirable genes for yield and dependability than do other plants within the same pool; these are retained for future recombination. After a number of cycles of thorough recombination and selection, the pools are in a position to contribute useful germplasm with superior sources of genetic diversity to the more advanced maize populations. Thirteen of CIMMYT's existing advanced maize populations have now been enriched through the introduction of superior maize families promoted from their corresponding gene pools. In addition, three subtropical/temperate populations have been newly formed from families drawn from the corresponding gene pools.

Sharing of pools with national collaborators

Increasingly, CIMMYT is sharing its maize pools with national collaborators. Many of these pool materials are proving to be extremely useful to national scientists as they seek to develop high yielding varieties with good agronomic characteristics. In several cases, these pools have proven to be so superior when tested in different countries that families have been extracted to develop new varieties for national release. The use of pools 19 and 20 in Mexico, pool 16 in West Africa (SAFEGRAD program), and pool 17 in India are examples. While many national maize programs are not equipped to use the gene pools to best advantage, CIMMYT's policy of sharing pools with those maize programs with higher levels of scientific manpower and adequate financial resources has proved to be very beneficial and will continue.

Promotion of materials from the gene pools to the Advanced Unit populations

From back-up pool		No. fam.	To population		Proportion of advanced population (%)
(Pool 24)	T.L.W.D.	54	Tuxpeño 1	(Pop.21)	17
(Pool 24)	T.L.W.D.	10	Mezcla Tropical Blanca	(Pop. 22)	11
(Pool 23)	T.L.W.F.	36	Blanco Cristalino-1	(Pop. 23)	9
(Pool 21)	T.I.Y.F.	54	Mezcla Amarilla	(Pop. 26)	25
(Pool 25)	T.L.Y.F.	50	Amarillo Cristalino-1	(Pop. 27)	20
(Pool 26)	T.L..Y.D.	44	Amarillo Dentado	(Pop. 28)	10
(Pool 15)	T.E.W.F.	77	Blanco Cristalino-2	(Pop. 30)	58
(Pool 17)	T.E.Y.F.	30	Amarillo Cristalino-2	(Pop. 31)	4
(Pool 31)	Tm.I.W.F.	65	Blanco Subtropical	(Pop. 34)	9
(Pool 22)	T.I.Y.D.	52	Cogollero	(Pop. 36)	19
(Pool 26)	T.L.Y.D.	27	Cogollero	(Pop. 36)	20
(Pool 24)	T.L.W.D.	10	La Posta	(Pop. 43)	6
(Pool 30)	Tm.E.Y D.	169	Compuesto de Hungría	(Pop. 48)	43

New advanced populations contributed by Back-Up pools

From Back-Up pool		No. fam.	Population formed	
(Pool 29)	Tm.E.Y.F.	240	Templado Amarillo Cristalino-3	(Pop.46)
(Pool 32)	Tm I.W.D.	276	Templado Blanco Dentado	(Pop.47)
(Pool 33)	Tm.I.Y.F.	275	Amarillo Subtropical	(Pop.33)

POPULATION IMPROVEMENT

Within the CIMMYT maize improvement process, what we call our Advanced Unit is assigned the responsibility of refining the more advanced maize materials to the point where they are ready for systematic international testing and use by the majority of national programs.

In 1981, the Advanced Unit team worked on 26 different populations assembled on the basis of climatic adaptation, maturity, grain color, and kernel type. Each population undergoes a continuous selection process for a number of different traits, using a full-sib (full brother or full sister) breeding method. Variable priorities are given to different

traits for improvement according to the major problems in each population in relation to the geographic area it is meant to serve.

Each population undergoes selection using the within- and among-family variation. Populations are grown and improved for three generations in Mexico; in the fourth generation (or once every two years) they are tested in an international progeny testing trial at six locations worldwide. This system of population improvement, backed by a range of genetically diverse and useful gene pools and followed by an extensive program of multilocational testing, has resulted in the development of many broadly adapted and high-yielding maize materials for the subtropics and tropics.

Agronomic improvements

A historical problem with tropical maize has been its tall stature and leafy character and, hence, relatively low grain-to-stover ratio. In the CIMMYT program, major improvement objectives have been to: (1) partition total dry matter toward more grain production, and (2) to improve the

CIMMYT populations included in the international maize testing program, 1981-82

(Internationally tested in even years)		(Internationally tested in odd years)	
Pop. number	Name	Pop. number	Name
22	Mezcla Tropical Blanco	21	Tuxpeño 1
23	Blanco Cristalino-1	26	Mezcla Amarilla
24	Antigua Veracruz 181	28	Amarillo Dentado
27	Amarillo Cristalino-1	29	Tuxpeño Caribe
32	Eto Blanco	30	Blanco Cristalino-2
35	Antigua Rep. Dominicana	31	Amarillo Cristalino-2
39	Yellow Quality Protein Maize	36	Cogollero
43	La Posta	40	White Quality Protein Maize
		49	Blanco Dentado
33	Amarillo Subtropical	34	Blanco Subtropical
42	Eto-Illinois	41	Templado Amarillo Quality Protein Maize
44	AED-Tuxpeño		
45	Amarillo Bajio	46	Templado Amarillo Cristalino
47	Templado Blanco Dentado		
		48	Compuesto de Hungria

manageability of tropical maize for the farmer. A reduction in plant height helps in the achievement of both objectives.

Most of CIMMYT's maize populations now have generally acceptable plant height, high yield potential, and improved standability. A considerable number of the tropical lowland and highland populations, which originally were in the 3 to 4 meter height range, are now in the 2 to 3 meter range. In several new populations, such as population 49, based on Tuxpeño Crema I (cycle 17 of selection for reduced height), the average height is less than 2 meters and the grain-to-stover ratio is near 50:50, similar to the ratio of US Corn Belt materials (see table 1). A few CIMMYT populations, however, are still too tall, and considerable selection pressure is exercised within these populations to reduce height to more manageable levels.

Early maturity

For many tropical and subtropical maize areas, high-yielding varieties with earlier maturity are desired since they offer a number of potential benefits to certain farmers. In rainfed areas, an earlier variety provides more flexibility for planting dates. In other areas, a farmer may be able to increase his annual cropping intensity by using early-maturity maize varieties which allow him to add another crop to his annual production cycle.

Table 1. Comparison of various cycles of selection for reduced plant height in Tuxpeño Crema I when grown at or near its optimum density. (Data are means for two years at two locations: Poza Rica and Tlaltizapan, Mexico.)

Cycle of selection	Plant height (cm)	Grain yield (t/ha)	Total dry matter (t/ha)	Harvest index
0	273	4.05	14.94	0.30
6	211	5.54	14.75	0.38
9	203	5.67	15.32	0.39
12	196	6.18	15.37	0.41
15	173	6.73	15.12	0.46
17	156	6.23	13.10	0.47
20	143	6.79	13.60	0.49

Examples of CIMMYT's earlier-maturing populations to date (less than 90 days to maturity) are Blanco Cristalino-2 (pop. 30), a white semi-flint tropical material; Amarillo Cristalino-2 (pop. 31), composed of early families from several yellow flint tropical populations and crosses of tropical x temperate materials; and Templado Amarillo Cristalino (pop. 46), a new subtropical population with yellow flint grain. These early-maturity populations are now flowing to national collaborators through the international testing program.

Disease resistance

CIMMYT continues to improve its populations for disease resistance, using the recurrent selection schemes previously described.

Selection pressure is exercised continuously for resistance to ear and stalk rots (using artificial inoculation techniques) and for leaf blights and rusts (using reliable field inoculations). Results of international trials show that the level of resistance to these diseases has improved considerably in several populations.

The development of disease resistance is also accomplished through collaborative research with scientists located in areas affected by diseases not prevalent in Mexico. CIMMYT's collaborative research for downy mildew, corn stunt, and streak virus resistance are examples. Until 1980, a type of shuttle breeding procedure had been followed which involves the screening of approximately 500 families from selected populations for disease resistance in affected areas, the selfing of resistant plants selected in these areas, and the recombination of the resistant families in Mexico together with selection for desired agronomic characteristics.

For the downy mildew and corn stunt resistance, this procedure has been repeated for several cycles in three broad-based populations. Considerable progress has been made in building up the resistance to both downy mildew and corn stunt (see Table 2). These populations are now being used for the development of open-pollinated varieties for areas affected by downy mildew and corn stunt, and as sources to develop resistant inbred lines for national programs interested in hybrid development.

Beginning in 1980, CIMMYT shifted the center of activity in the downy mildew work, including the preparation and distribution of international progeny trials to appropriate areas, to the Asian regional maize program . Three Advanced Unit populations (pop. 22, 28, 31) are now being handled by this regional program. The corn stunt work continues to be centered in Mexico and Central America, again with full involvement of national scientists.

CIMMYT has joined with IITA and West African scientists in a collaborative effort to develop high-yielding varieties with resistance to streak virus, a major disease problem of tropical Africa.

Table 2. Progress in improving resistance to downy mildew and corn stunt

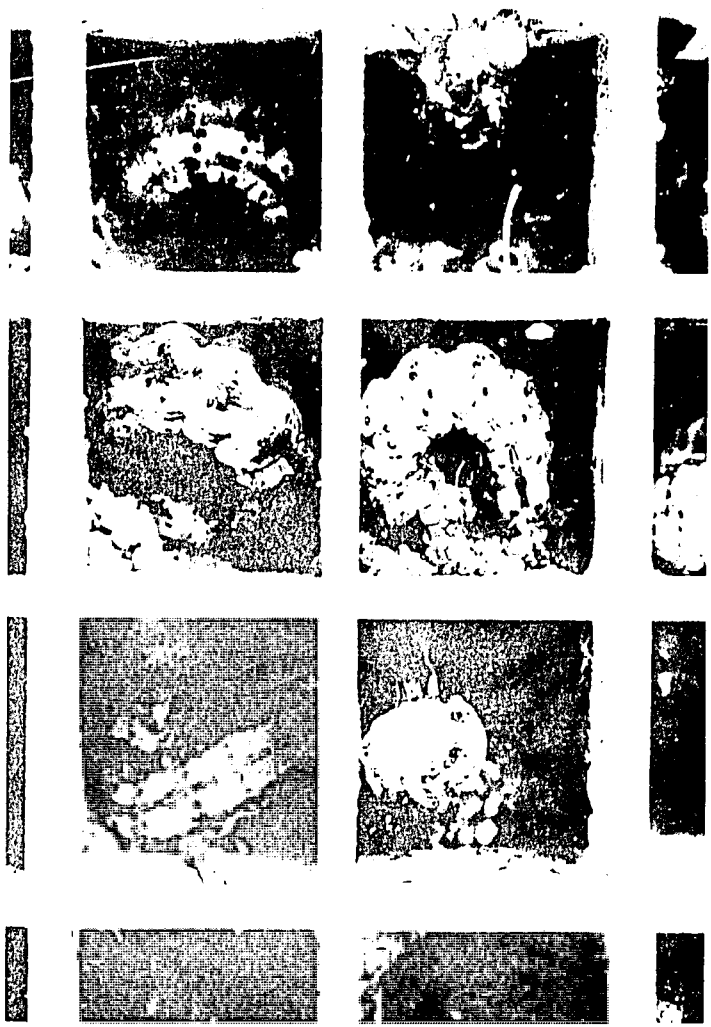
Population	Cycle of selection	% disease	Yield (kg/ha)	Plant ht. (cm)	Days to 50% silk
Downy mildew (Thailand)					
1. Tropical Intermediate White Flint	C_0	41.4	3836	185	68
	C_4	0	4404	160	66
2. Tropical Yellow Flint-Dent	C_0	67.4	2684	199	68
	C_4	2.6	4490	183	66
Corn stunt (El Salvador)					
1. Tropical Intermediate White Flint	C_0	30.6	3337	206	49
	C_4	21.8	4120	200	49

The progress on streak virus resistance has been slower than that on downy mildew and corn stunt. One limitation has been the lack of an insect-rearing facility (streak virus is transmitted by a leaf hopper) located in virus-affected areas to carry out uniform inoculation and disease screening. We have now joined with IITA and West African scientists in a collaborative research effort on this important African disease problem. Using CIMMYT's population La Posta (pop. 43), a tropical lowland white dent material, and sources of streak virus resistance developed by IITA scientists, we have stepped up our efforts to develop high-yielding, streak-resistant varieties for production conditions in Africa.

Insect resistance

Insect damage is a serious yield-limiting problem in tropical and subtropical maize areas. Effective and judicious use of insecticides would appear to be an easy solution to the problem, but the unavailability and/or relatively high cost of insecticides in the developing world often make this an unpracticed solution. Consequently, breeding for resistance to insects is a major CIMMYT research objective.

In Mexico, different populations are infested with the larvae of fall armyworm, corn earworm, Southwestern corn borer, or sugarcane borer. These are the most important maize pests found in Mexico (and in the western hemisphere) and are related to species causing serious damage on other



CIMMYT's insect-rearing laboratory was established to produce enough insect larvae to artificially infest and screen maize pools and populations for insect reaction to prevalent and important insects. Each year, millions of larvae are produced to infest the various pools and populations.

continents. For example, Tuxpeño (pop. 21) and Antigua-Veracruz 181 (pop. 24), both lowland tropical materials, are being improved for resistance to the fall armyworm (*Spodoptera frugiperda*). Two tropical lowland populations, Amarillo Cristalino-1 (pop. 27), and Blanco Cristalino-1 (pop. 23), are being improved for resistance to the sugarcane borer (*Diatraea saccharalis*). One subtropical population, Templado Blanco Dentado 2 (pop. 47), is being improved for resistance to the Southwestern corn borer (*Diatraea grandiosella*). At different growth stages after infestation, visual ratings for insect damage are made for each family. Progenies showing the least damage are retained for recombination and use in future improvement cycles.

A Ph.D. student is currently evaluating the potential and progress in improving insect resistance in two CIMMYT populations.

NUTRITIONAL QUALITY IMPROVEMENT

Since 1970, with UNDP funding, CIMMYT's maize program has included work on the nutritional quality aspects of maize improvement. Today, this work is an integral part of the total maize research program and some of the materials undergoing improvement in the Back-Up and Advanced Units have parallel counterparts in the quality protein maize program.

CIMMYT's quality protein maize carries a mutant gene called opaque-2. Maize carrying this gene has enhanced levels of lysine and tryptophan—two essential and limiting amino acids for protein quality in maize. The original opaque-2 quality protein maize had an unacceptable dull soft kernel, low yield potential, greater vulnerability to ear rots and storage pests, and slower drying after physiological maturity.

To remedy these problems, CIMMYT scientists exploited a number of genetic modifiers to develop hard endosperm opaque-2 materials which look like normal maize but still retain their superior nutritional quality. These efforts to accumulate genetic modifiers have demonstrated conclusively

that most of the problems associated with the soft opaque-2 materials can be overcome through careful and systematic selection for hard endosperm opaque-2 kernels.

The breeding approaches and selection procedures used in the quality protein maize program are essentially the same

Three quality protein maize populations have formed part of the international testing program since 1978. These populations undergo three cycles of improvement in Mexico followed by international progeny testing trails at six locations worldwide.

as those used to improve normal maize. The only modification is a backcrossing and recurrent selection scheme needed to introduce and maintain the opaque-2 gene and to accumulate the desired modifiers for endosperm hardness.

The progress made over the last 10 years in the development of hard endosperm quality protein maize is an impressive research achievement. The problems of reduced yield, vulnerability to ear rot and stored grain pests, and the dull and chalky kernel appearance have been largely overcome. We now have various normal-looking quality protein maize materials which are equal or superior in yield to many normal check varieties under cultivation in Latin America, Africa, and Asia (see Table 3).

Three quality protein maize (QPM) populations have been part of the international testing program for several years. Two of the populations, Yellow QPM (pop. 39) and White QPM (pop. 40), are adapted to lowland tropical and subtropical areas. The other, Templado Amarillo QPM (pop. 41), is adapted to subtropical regions. Other outstanding populations now ready for international testing include Tuxpeño-1 QPM, Late White Dent QPM, La Posta QPM, Blanco Cristalino QPM, Templado x Tropical QPM, Temperate White QPM, and Amarillo Bajio x Maices Argentina QPM.

Table 3. Yield comparisions of the best quality protein maize experimental varieties with the best normal checks at selected locations in EVT 15A, 1980

Country	Site	Best normal check	Yield t/ha	Best QPM-EV	QPM EV yield, as % of best check
Brazil	Sete Lagoas	CMS-95	6.9	Ferke 7940	113
Ecuador	Pichilingue	Pichilingue 504	5.6	Poza Rica 7940	107
Venezuela	Durigua	Local	3.1	Across 7740	127
Zaire	Kanima	Kasai-1	6.9	Obregon 7940	101
Mali	Sotura	IRAT-85	3.9	Guanacaste 7940	127
Bangladesh	Jessore	J_1	9.2	Guanacaste 7940	108

In 50-60 percent of the countries reporting data from recent international testing trials, outstanding QPM materials have shown yield potential similar to the best check varieties. Among the experimental varieties included in recent EVTs and ELVTs, the following varieties have performed very well: Across 7740, Obregon 7740, Guanacaste 7940, Ferke 7940, Across 7741, and Chuquisaca 7741.

New research directions

Researchers continue to improve kernel weight and yield and to develop higher levels of resistance to ear rot in our QPM materials. They also are working on methods to genetically isolate quality protein maize, to reduce the amount of pollen contamination (and potential loss of protein quality) that may occur from normal materials grown nearby. Some new exploratory research is also under way to improve other nutritional quality aspects of maize, such as oil content.

CIMMYT scientists have shown that it is possible to combine the beneficial effects of the opaque-2 gene with superior yield, and that quality protein maize can be commercially exploited. For example, in Guatemala several QPM materials are being grown on a commercial scale for use in nutrition intervention programs conducted by the Nutrition Institute for Central America and Panama (INCAP).

INTERNATIONAL TESTING

CIMMYT begins to distribute populations and varieties through the international testing program as soon as they are considered to be sufficiently advanced (improved) to be of use to scientists in national programs. This international testing program is designed to: (1) combine into one mechanism a system for continuous improvement of maize germplasm and a delivery system to and from national programs, and (2) serve national programs that are at different stages of development. A key feature in this system is the partnership role that national scientists play in the improvement of populations and the development of experimental varieties.

Distribution of international maize trials, 1979-81

Region and nation	1979 trials	1980 trials	1981 trials
Central America and Caribbean	**188**	**199**	**137**
Bahamas	4	1	1
Barbados	3	2	2
Belize	6	5	3
Costa Rica	12	8	8
Dominican Republic	4	11	12
El Salvador	10	8	4
Grenada	1	1	1
Guatemala	15	20	10
Haiti	10	10	0
Honduras	14	19	12
Jamaica	12	3	3
Mexico	62	69	41
Nicaragua	11	9	9
Panama	16	24	28
St. Kitts	1	1	0
St. Vincent	1	0	0
Trinidad	6	8	3
South America	**105**	**132**	**101**
Argentina	10	13	4
Bolivia	11	14	10
Brazil	28	23	38
Chile	5	2	0
Colombia	15	10	2
Ecuador	10	14	7
French Guiana	4	2	0
Paraguay	0	2	5
Peru	13	31	19
Surinam	4	5	0
Uruguay	0	0	2
Venezuela	5	16	14
Mediterranean/Mideast	**53**	**51**	**41**
Algeria	2	2	0
Egypt	7	11	7
Iraq	2	2	4
Jordan	4	2	0
Libya	3	0	2
Morocco	2	3	3
Saudi Arabia	6	6	6
Syria	3	3	0
Tunisia	2	0	0
Turkey	3	12	9
Yemen A.R.	13	6	10
Yemen, South	5	4	0
Sub-Saharan Africa	**165**	**289**	**204**
Angola	0	3	2
Benin	2	6	5
Botswana	3	4	2
Burundi	0	13	0
Cameroon	6	8	8
Central African Republic	0	0	2
Chad	2	0	0
Congo	0	6	2
Comoros	0	0	2
Ethiopia	9	21	10
Ghana	3	8	8

Distribution of international maize trials, 1979-81 (con't)

Region and nation	1979 trials	1980 trials	1981 trials
Guinea	0	0	2
Guinea-Bissau	3	4	4
Ivory Coast	10	14	9
Kenya	6	16	7
Lesotho	3	6	0
Malawi	6	19	12
Mali	4	6	4
Mauritania	0	2	2
Mozambique	17	22	8
Niger	1	0	1
Nigeria	26	31	10
Rep. South Africa	4	11	11
Reunion	2	1	8
Rwanda	4	6	0
Senegal	7	13	6
Sierra Leone	9	17	21
Somalia	6	4	4
Sudan	3	2	6
Swaziland	2	5	7
Tanzania	9	7	5
Togo	1	4	4
Transkei	0	4	2
Uganda	2	6	5
Upper Volta	3	8	11
Zaire	8	8	4
Zambia	4	4	4
Zimbabwe	0	0	6
South and East Asia	**89**	**103**	**81**
Afghanistan	4	0	0
Bangladesh	7	5	4
Burma	6	8	6
India	16	24	12
Indonesia	3	3	2
Korea, South	2	2	2
Malaysia	4	6	3
Nepal	12	7	5
Pakistan	12	17	12
Philippines	12	10	9
Sri Lanka	3	5	6
Thailand	8	12	12
Vietnam	0	4	8
Other	**16**	**13**	**14**
Greece	4	4	2
Hungary	2	0	0
New Guinea	6	0	0
Puerto Rico	1	3	0
Spain	0	2	0
Tahiti	3	1	1
USA	0	0	6
Yugoslavia	0	3	5
TOTAL TRIALS	615	787	578
TOTAL COUNTRIES	84	88	84

The program ships seed of two categories of material. Progeny trials from advanced unit populations are shipped to as many as six locations for each population. A progeny trial is large, consisting of 256 entries replicated twice, and is used to select superior progenies at each location and across all locations for production of new experimental varieties. These varieties enter into Experimental Variety Trials (EVTs) consisting of 10 to 40 varieties replicated 4 times. An EVT is grown at as many as 60 locations. The results are used to select the superior 30 to 50 percent of the EVs for testing again in the Elite Variety Trial (ELVT). The national program grows the trial, collects appropriate data, and returns the data to the international testing program for analysis. The results are published twice yearly and distributed to cooperators.

In 1981, CIMMYT shipped 578 trials at the request of national collaborators in 80 countries. Because of a modification in the international testing program, only international progeny testing trials (IPTTs) and elite experimental variety trials (ELVTs) were distributed in 1981. The normally distributed experimental variety trials (EVTs) were held up for one year in order to include second generation experimental varieties instead of first generation materials in the different EVTs. This modification will provide more reliable estimations of yield potential in the EVs distributed to collaborators in the future. (The distribution of EVTs with F_2 experimental varieties has been resumed in 1982.)

The report that follows is based upon the 1980 international testing program, since the final report is available on those trials.

International progeny testing trials (IPTTs)

A total of 66 IPTTs, developed from 11 Advanced Unit populations, were distributed in 1980 to cooperators in 28 countries. These international progeny trials serve two purposes. First, about 10 of the best families from each population are identified at each testing site by national collaborators to form a new experimental variety. In addition, the 10 best families, on the basis of performance across all sites where a particular IPPT is grown, are used to form a new "across-site" experimental variety. Second, 30 to 40 percent of the best performing families in each IPTT are selected to regenerate the population for the next improvement cycle.

Experimental variety trials (EVTs)

In 1980, seven different EVTs were assembled and 419 sets were distributed to national collaborators upon request. Two quality protein maize trials, EVT 15A and EVT 15B, consisting of 12 and 5 quality protein maize (QPM) experi-

Over the last four years, CIMMYT has received reports of more than 70 varieties and hybrids being named and released by national collaborators in 22 countries. These superior maize varieties were derived from materials selected from the CIMMYT international testing program.

mental varieties respectively, were also included. In Table 4, some of the best-performing EVs are compared to the best normal protein quality check varieties (or hybrids) used at the individual sites where the particular trial was grown.

Elite experimental variety trials (ELVTs)

The best-performing experimental varieties across all locations in previous EVTs are selected to form subsequent

Table 4. Selected high-performing EVs from 1980 EVTs

Test site	1980 EVT number	Name of top experimental variety (EV)	Yield (kg/ha)	Yield of EV as % of best check
Latin America				
Bolivia (Iboperenda)	12	Across 7843	10,537	109
Bolivia (Iboperenda)	12	Across 7822	10,390	107
Brazil (Sete Lagoas)	12	Cotaxla 7822	9,998	141
Mexico (Tlaltizapan)	16	Across 7842	9,034	106
Mexico (Obregon)	12	Across 7822	7,050	133
Venezuela (San Joaquín)	12	Across 7822	6,696	116
Venezuela (Macapo)	12	Cuyuta 7929	5,578	133
	13	Pichilingue 7827	5,732	130
Brazil (Guaira)	15A	Poza Rica 7940 (QPM)	6,402	139
Africa				
Benin (Sekou)	12	Poza Rica 7921	5,589	135
Burundi (Imba)	12	Across 7843	7,467	149
Malawi (Chitala)	12	Across 7483	4,775	126
Mozambique (Umbeluzi)	13	Across 7824	4,463	145
Mali (Sotuba)	14B	Jutiapa (1) 7930	3,765	136
Mozambique (Lioma)	15B	Temp x Trop $HE_0 2$ (QPM)	5,591	129
Burundi (Mosso)	16	Across 7842	7,349	140
Mozambique (Mutireli)	16	Across 7844	6,090	110
Asia				
Burma (Yezin)	13	Ferke 7928	6,234	149
Nepal (Rampur)	16	Across 7842	10,609	134
Pakistan (Pirsabak)	16	Sao Paulo 7842	6,701	132

new elite variety trials. In 1980, four ELVTs were assembled and 290 sets were requested by national collaborators. One quality protein maize trial (ELVT 19) was included, consisting of four QPM elite varieties and eight populations. Table 5 lists some of the best performing ELVs compared to the best checks where the trials were grown.

Table 5. Sampling of best-performing ELVs from 1980 ELVTs

	1980 ELVT number	Name of top ELV	Yield kg/ha	Yield of ELV % of best check
Latin America				
Bolivia (Iboperenda)	18A	San Andres(2)7530	8,794	142
Brazil (Guaira)	18A	Poza Rica 7728	6,253	120
Brazil (Sete Lagoas)	18A	Poza Rica 7822	8,704	134
Colombia (Turipana)	18A	Ferke (1)7622	3,983	181
Honduras (Catacamas)	18A	Omonita 7643	8,083	124
Panama (Progreso)	18B	Across 7726	4,609	124
Venezuela (Acarigua)	19	Across 7740(QPM)	4,001	136
Argentina (Pergamino)	20	Tlaltizapan 7844	8,086	106
Africa				
Burundi (Imbo)	18A	Across 7729	6,671	141
Ivory Coast (Ferke)	18A	Guanacaste 7729	4,917	144
Sudan (Halima)	18A	Guanacaste 7729	5,223	134
Swaziland (Malkerus)	18A	Across 7643	4,611	138
Burundi (Mosso)	20	Tlaltizapan 7844	7,585	116
Mideast				
Jordan (Deir Alla)	20	Tlaltizapan 7734	4,183	125
Saudi Arabia (Hofuf)	20	Tlaltizapan 7734	4,085	133
Turkey (Antalya)	20	Across 7734	7,645	122
Asia				
Bangladesh (Joydebpur)	18A	Poza Rica 7728	6,475	112
Burma (Yezin)	18A	Across 7643	7,454	129
Pakistan (Pirsabak)	18B	Across 7635	6,210	122
Philippines (Karaan)	18B	Tocumen (1)7835	3,349	142
India (New Delhi)	19	White H.E.o_2-RSF (QPM)	3,197	114

Release of new varieties by national programs

It is the responsibility of national programs to name and release improved maize varieties for their countries. Many countries are using CIMMYT-distributed experimental varieties as direct releases or as breeding materials in their improvement programs. While our information is incomplete on national releases of varieties and hybrids derived from materials included in CIMMYT's international testing program, we do have reports of 69 varieties and hybrids being released in 22 countries over the last five years. Although CIMMYT emphasizes the development of open-pollinated varieties as the end product of its population improvement work, these materials are also proving to be of great use in hybrid development. In fact, of the new varieties released by various countries, 25 percent are hybrids. Indeed, CIMMYT's extensive population improvement program has been extremely useful for recent hybrid development in the tropics and subtropics.

Reports of maize varieties released by national programs based on CIMMYT-distributed germplasm, 1977-81

Latin America

- Colombia (2)
- Costa Rica (4)
- Dominican Republic (2)
- Ecuador (3)
- El Salvador (3)
- Guatemala (13)
- Haiti (2)
- Honduras (8)
- Mexico (6)
- Nicaragua (2)
- Panama (1)
- Peru (2)
- Venezuela (1)

Africa

- Ivory Coast (3)
- Lesotho (1)
- Swaziland (2)
- Tanzania (1)
- Zaire (4)

Asia

- Burma (4)
- China (2)
- India (2)
- Nepal (1)

SPECIAL RESEARCH ACTIVITIES IN MEXICO

Within the general maize improvement program, new ideas and techniques, as well as some special research activities, are carried out as special research projects. These studies may require many years for completion, but the conclusions reached may lead to modifications in the improvement priorities and/or methodologies used within overall program activities. Three special research projects will be reported here—drought tolerance, early maturity, and wide crosses.

Drought tolerance

CIMMYT scientists have been, studying the genetic variation for performance under water-stress in one population, and are exploring the reliability of easy selection criteria for the development on a field scale of drought-tolerant types. The objective is to determine whether drought-tolerant maize varieties can be developed with superior yield potential under both stress and non-stress conditions.

The parameters used for the evaluation of drought tolerance under a multiple selection index are: (1) relative leaf elongation rate, (2) interval between pollen shed and silking, (3) leaf tissue death, (4) grain yield under stress and non-stress conditions, and (5) canopy temperature.

The results to date (*vis* drought resistance), as shown in Table 6, confirm that (a) there is a genotype x moisture interaction (i.e., that some plants can handle stress better than others) and (b) that a multiple selection criteria can be used to identify genotypes (families) that give better than average performance under moisture stress without detriment to their performance under more favorable conditions (i.e., with no moisture stress).

Table 6 also compares materials selected, using the drought resistance criteria, with other CIMMYT materials. Particularly interesting is the performance under drought stress of the yield efficiency materials, such as the materials with reduced height, tassel, and leaf area. In addition, population 21, which is part of the normal international testing program, is also showing improved yield dependability under drought stress (as well as higher yield potential) as a result of the multilocational testing scheme used by CIMMYT.

Table 6. Grain yield comparisons for different selection criteria in the population Tuxpeño under irrigation and stress conditions (Tlaltizapan, 1981)

Selection criteria	Cycle	Grain yield (kg/ha) Irrigation	Stress
Reduced height	6	5276	1129
	12	5358	1203
	15	5893	1718
	18	6129	1570
Reduced tassel	0	5608	1213
	6	6172	1673
Reduced leaf	0	5608	1213
	5	6196	1468
Drought resistance	0	5859	1224
	3	6179	1572
	+EV	6311	1647
Population 21 (part of international testing program)	0	5608	1213
	3	6458	1315

+ Experimental variety (EV) (4% selection pressure)

Early maturity in tropical maize

CIMMYT is experiencing a growing demand for earlier maturing materials to fit into a brief rainy season or more intensive cropping systems. A special research project was initiated in 1975 to examine different approaches to develop materials with earlier maturity. The sacrifice in yield associated with earlier maturity as well as heightened problems of diseases and insects (due to earlier plant development than in the surrounding plant types) have long been identified as the major breeding challenges associated with the development of these materials.

One of the research approaches used in this project was to assemble a number of high-yielding genotypes with intermediate maturity into a population (called Compuesto Selección Precoz) in which recurrent selection is practiced for earliness. Ten cycles of selection have now been completed.

In 1980-81, a trial was designed to evaluate the first eight cycles of selection.

One of the conclusions of the trial is that as one selects for earliness the plant type, one also tends to get shorter and more manageable. The second is that recurrent selection can be used to reduce substantially days-to-maturity without adversely affecting yield potential (when planting density is increased).

Some early-maturing families from the population Compuesto Seleccion Precoz developed through this project have been used to form two new Advanced Unit populations (pop. 30 and 31). Studies are continuing in this project to look at the effects of other factors, such as the length of pre- and post-flowering phases on subsequent maturity characteristics.

Wide crosses

Crosses between maize and two alien genera, sorghum and *Tripsacum*, are being pursued to determine the feasibility of using potentially useful genes from these genera for maize improvement. The aim is to make maize a more environmentally stable crop with better insect and disease resistance (using genes from *Tripsacum*) and more drought and waterlogging tolerance (using genes from sorghum).

In 1981, existing cytological techniques were adapted and used to differentiate maize chromosomes from sorghum and tripsacum chromosomes. Chromosome banding was used to confirm the hybrid nature of the maize x *Tripsacum* classical hybrids that are being maintained in El Batan and Tlaltizapan. At present, only the classical maize x *Tripsacum* hybrids involving three different types of *Tripsacum* parents have survived. More work is being undertaken to re-isolate the maize x *Tripsacum* hybrids that have been lost and to isolate new hybrids involving different maize x *Tripsacum* parents.

Further work on embryo culture has been carried out and a satisfactory media for the production of seedlings from immature embryos has been determined.

At present the major emphasis is being placed on increasing the number of maize x sorghum cross pollinations made, in order to increase the probability of achieving new hybrids for further study.

MAIZE TRAINING

CIMMYT offers a wide range of training opportunities to scientists working in maize improvement and production in the developing world. These include:

- In-service training courses in:
  - production agronomy
  - maize improvement
  - laboratory analysis
  - experiment station management
- Graduate student programs in cooperation with universities: a few students spend 12 to 18 months in Mexico to do thesis research
- Postdoctoral fellows: 1-2 years service at CIMMYT
- Visiting and associate scientists: up to 1-year fellowships at CIMMYT

In-service training

The in-service training program is now eleven years old. Over 600 trainees from 61 countries have completed the six-month training courses. In 1981, trainees from 20 countries participated in one of the four in-service training programs. Of these, 34 participated in the production agronomy course, 11 in the maize improvement course, 5 in the experiment station management course, and 3 in protein quality laboratory training.

Production agronomy is the largest of CIMMYT's in-service training courses. It emphasizes procedures to organize and execute a systematic program of on-farm surveys and experiments designed to identify agronomically and economically sound production recommendations. An active field research program is carried out and trainees remain in Mexico for a full production cycle. Production trainees are also exposed to CIMMYT's overall maize improvement program . In recent years, seed production procedures have been stressed more, and production trainees now help to manage breeders' seed-increase plots needed by CIMMYT to provide experimental quantities of seed to collaborating national programs.

In the maize improvement course, trainees are introduced to the range of breeding materials handled by CIMMYT at its different experiment stations. Emphasis is given to the field research skills needed to design and manage a maize

More than 600 trainees from 61 countries have now completed one of four CIMMYT maize in-service training programs. These young scientists are playing key roles in their respective national maize programs.

improvement program. This practical training is interspersed with participation in the agronomy experiments conducted by the production trainees on farmers' fields, and with classwork related to the breeding methodologies used by CIMMYT scientists.

Graduate student training and doctoral fellows

During 1981-82, with outside financial sponsorship, CIMMYT is cooperating in the training of six master's degree

candidates (El Salvador, Ghana, Honduras, Panama, and Zaire). In addition, one Ph.D student (USA) is engaged in thesis research in Mexico, and four postdoctoral fellows (Australia, Hong Kong, USA, and Yugoslavia) are serving on the maize program staff.

Maize in-service trainees, 1971-81

Region and country	1971-81	1981
Central America and Caribbean	**174**	**11**
Belize	6	0
Costa Rica	10	0
Dominica	1	0
Dominican Republic	14	1
El Salvador	22	0
Grenada	1	0
Guatemala	17	0
Guyana	1	0
Haiti	13	0
Honduras	25	0
Mexico	32	4
Nicaragua	18	1
Panama	14	2
South America	**88**	**5**
Argentina	11	0
Bolivia	10	0
Brazil	3	0
Colombia	13	2
Chile	2	0
Ecuador	19	1
Peru	22	2
Venezuela	8	0
South and East Asia	**150**	**20**
Afghanistan	6	0
Bangladesh	9	2
Burma	1	1
India	10	0
Indonesia	3	0
Japan	7	0
Korea	2	0
Malaysia	3	0
South and East Asia (Con't)		
Nepal	20	0
Pakistan	36	8
Philippines	20	0
Thailand	31	7
Vietnam	2	2
N. Africa and Mideast	**38**	**2**
Algeria	1	0
Egypt	17	0
Syria	1	0
Tunisia	3	0
Turkey	13	2
Yemen A.R.	3	0
Tropical Africa	**154**	**18**
Botswana	2	0
Cameroon	1	0
Cape Verde	1	1
Ethiopia	6	2
Ghana	22	8
Ivory Coast	4	0
Kenya	5	0
Malawi	4	2
Mozambique	3	3
Nigeria	12	0
Rwanda	1	0
Senegal	1	0
Swaziland	1	0
Tanzania	52	0
Transkei	1	0
Uganda	1	0
Zaire	31	1
Zambia	6	1
Other	**3**	**1**
Total training fellows	**603**	**53**
Total countries	**61**	**2[illegible]**

Visiting scientists

During 1981, the maize program received 19 visiting and associate scientists who spent from one week to one year in Mexico. Many short-term visitors, often agricultural policy makers and research administrators, were also received.

MAIZE COOPERATIVE PROJECTS OUTSIDE MEXICO

A number of regional programs have emerged among various maize-growing countries, and CIMMYT has posted staff to support these regional efforts. In a few collaborating countries, CIMMYT has received special funds to assign staff members to work within a national program, usually during its more formative stages.

National programs

In 1981, CIMMYT had maize staff posted in three national programs. These staff work on a daily basis with national program scientists in all aspects of maize improvement and production research and in training and staff development activities.

Cooperative projects involving national programs, 1981

Country	Start of CIMMYT arrangement	CIMMYT staff assigned	Donor
Pakistan	1970	1	USAID
Tanzania	1973	1	USAID/IITA
Ghana	1979	1	CIDA(Canada)

Regional programs

A regional program helps to forge stronger links among national collaborators and with CIMMYT. Regional programs generally comprise neighboring countries in which maize is a major crop (or has the potential of becoming one), grown

under similar conditions, and exposed to similar diseases and insects. Therefore, these countries benefit from close collaborative research, training, and information activities as well as from the exchange of germplasm. Another research dimension in regional program activities involves the shifting of portions of CIMMYT's international breeding program to regional bases, with the cooperation of national scientists in each area.

Regional maize programs in 1981

Region and operations base	Number of cooperating countries	Start of CIMMYT arrangement	CIMMYT staff assigned	Current donor
Central America and Caribbean (Mexico and Guatemala)	13	1974	2	Switzerland
South and Southeast Asia (Thailand)	11	1976	2	UNDP/ Rockefeller Foundation
Andean countries (CIAT, Colombia and Ecuador)	5	1976	3	Core Unrestricted
Mideast (Turkey)	9	1979	1	Core Unrestricted
West Africa (IITA, Nigeria)	13	1980	2	Core Unrestricted

Central America, Mexico, and Caribbean regional program

The efforts of the maize staff assigned to this region are aimed at strengthening national maize improvement and production research programs in Central America and the Caribbean. Considerable progress has been made in maize improvement and production research throughout the region. Over 35 improved varieties have been released and many are in commercial production. National yield levels in most Central American countries have increased considerably over the last few years.

In 1981, regional staff assisted in conducting the international maize trials distributed to area countries. They also

assisted in the assembly, distribution, and data evaluation of the PCCMCA (Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimentícios) trials distributed throughout the region.

In maize improvement, particular emphasis was placed on greater corn stunt resistance, adaptation to conditions of drought stress, improved husk cover, reduced ear rots, and on the development of earlier varieties. On-farm research also continued to receive a major program focus, with weed control and minimum tillage methods given major emphasis. Major collaborative activities were under way in Honduras and Haiti.

Beginning in 1982, a third CIMMYT staff member was added to this regional program as part of a collaborative research arrangement with Mexico. The focus of his activities is on the identification of high-yielding open-pollinated varieties for Mexico's varied maize-production areas.

South and Southeast Asian regional program

The operations base for this program was shifted in 1980 from India to Thailand. A maize pathologist, deputed from the Rockefeller Foundation, assumed CIMMYT's regional responsibilities for its downy mildew international breeding program. Activities include disease screening and selection of resistant materials for international testing. Added emphasis is also being given to the development of earlier-maturity varieties. Good progress is being made to improve the downy mildew resistance of three advanced unit populations for lowland tropical areas (pop. 22, 28, 31). International trials will be distributed during 1982.

In late 1981, a regional agronomist was added to the program. His work focuses on production-oriented problems in the region, emphasizing on-farm research activities.

Andean regional program

CIMMYT has three maize scientists assigned to this region: one is headquartered in Ecuador with responsibilities for highland floury maize breeding, and two are stationed in Colombia from where they support tropical maize breeding and production research activities throughout the region.

Highland floury gene pools with varying maturity characteristics are contributing to the development of new high yielding varieties for the Andean region. A CIMMYT scientist is based in Ecuador to assist in this improvement work.

In the highland floury maize breeding program, eight gene pools have now been assembled. The aim of this program is to develop high yielding, widely adapted, earlier maturity floury maize varieties with improved insect and disease resistance. Some of the pools have now gone through two to

three cycles of selection. Improvement cycles are carried out in the same crop year by CIMMYT's Back Up Unit staff in Mexico and the staff member based in Ecuador. In this scheme, selection pressure for ear rot and earworm is applied in Mexico and for agronomic improvement in Ecuador.

A number of improved tropical highland and lowland maize varieties have now been developed by national program scientists using germplasm extracted from CIMMYT's international testing program and improved varieties have been released in Colombia, Ecuador, Peru, and Venezuela.

On farm research collaboration continues to receive considerable attention by the CIMMYT regional agronomist. In particular, he has been active in assisting the national programs of Colombia, Peru, and Venezuela in planning and implementing on farm production research programs.

Mideast regional program

A CIMMYT maize scientist, formerly assigned to Egypt, was shifted to a regional post in 1979, with his operations base in Turkey. His efforts in the region focus on strengthening national population improvement research and on introducing and testing exotic germplasm for utilization in the region. On farm testing and farmer surveys continue to receive emphasis.

During 1981, the Egyptian national maize program launched a major research extension effort to disseminate the high yielding, late wilt resistant, open pollinated variety, Giza 2. Two new Egyptian seed companies were established which produced 2,000 tons of Giza 2 certified seed. New inbred lines are being developed from superior families in populations 29 and 34. Several EVs (i.e., from pop. 21, 26, 32, 34, 42, and 44) developed through the IPTT system were identified to serve as germplasm sources for the main national populations.

In Turkey, one advanced unit population (pop. 48), a temperate yellow dent material suited to the region, is being specifically improved for resistance to *Helminthosporium turcicum* and stalk rot. Efforts were made to exploit USA germplasm for hybrids and population development. Materials from the early pools were identified to strengthen the early populations.

West African regional program

In 1980, CIMMYT posted a maize scientist to Nigeria as part of a cooperative regional effort with IITA and West African national programs. With this posting, CIMMYT has shifted its international breeding program for streak virus resistance to this regional base, with full involvement of IITA and West African maize scientists. The improvement work centers on developing streak resistance in CIMMYT's population La Posta (pop. 43), a tropical lowland white dent material which has shown high yield potential in Sub-Saharan Africa where this disease is not a problem. Considerable priority is given to this research since streak virus is one of the most serious disease problems in Sub-Saharan tropical maize areas. (In early 1982, a second CIMMYT maize breeder was assigned to this program.)

wheat improvement

INTRODUCTION TO THE WHEAT PROGRAM

CIMMYT, with a global mandate for wheat research, attempts to serve the major small grain producing areas of the developing world. Over the last 16 years, the wheat program has expanded in scope to include research on bread wheat, durum wheat, triticale, and barley. We endeavor to maintain the widest possible variation in our germplasm so that materials are available for all important production regions.

In 1981, improved germplasm was distributed to collaborating scientists in 103 countries. Included in this international testing program were materials with high yield potential for irrigated and rainfed areas, with resistance to many of the major small grains diseases, and with increasing tolerance to a range of agroclimatic stresses.

CIMMYT's crop improvement work continues to be dominated by yield dependability criteria. We place a heavy emphasis on disease resistance, primarily to the rusts, but also to many other of the 40 species of fungi, bacteria, and viruses known to be parasitic on wheat, barley, and triticale.

Our collaborative research with Brazilian scientists has resulted in the development of high yielding, aluminum tolerant wheat lines. When additional disease resistance is incorporated into these materials they will be suitable for millions of hectares of land characterized by acid soils and aluminum toxicity problems. In this research effort, we are also discovering lines with a greater capacity to extract phosphorus, an important factor for improved plant nutrition in areas with high phosphorus fixing soils.

Work on temperature and moisture stresses is also showing promise. Efforts to develop added cold tolerance in durum wheat and bread wheat have resulted in a number of advanced lines with markedly improved tolerance. Spring x winter lines are also exhibiting improved tolerance to stress problems such as drought. They may also offer good prospects for developing materials with enhanced heat tolerance, especially during tillering.

High-yielding lines with earlier-maturity characteristics is another research area being given increased emphasis. Such varieties are particularly important for a number of non-traditional wheat-growing countries in which only a relatively short season is available for producing wheat.

We are continuing our work on triticale, a hybrid cross of wheat and rye. This new crop has shown better adaptation than wheat in a number of production environments. In areas prone to certain heavy disease attacks, in cool highland environments, and in areas with acidic soils, triticales have shown a capacity to considerably outyield wheat. For such areas, triticale offers the prospect of a more dependable small grain crop to supply national requirements for bread and other flour based food products.

Motivated in part by the advances made in triticale, we are pursuing new wide cross research activities involving wheat and other genera species related to wheat. In this research we are not seeking to develop new crops but rather to introduce useful genes from various alien genera into wheat to further improve adaptation, dependability of yield, and grain quality characteristics.

In the pages which follow, highlights of the 1981 wheat program are given. It is an exciting program with a distinguished research legacy. To stand guard over the gains already achieved through the introduction of CIMMYT's high yielding semidwarf materials, a considerable amount of maintenance-type research, especially in disease resistance, must continue. Many new research initiatives are also under way to address the problems of improved yield potential and dependability in rainfed wheat areas. To help unravel some of the more fundamental problems associated with yield dependability, we are also expanding our collaborative links with other research centers. We are confident that significant research payoffs can continue to emerge from this program of work in the years ahead.

B. C. Curtis

BREAD WHEAT

The bread wheat program is the largest of CIMMYT's small grains improvement programs. Breeding activities have broadened over the years from an original emphasis on the development of semidwarf types with good rust resistance, toward the problems of rainfed wheat production and a host of other disease and stress problems.

These expanding activities are a natural consequence of CIMMYT's cooperation with an increasing number of national wheat programs in the developing world. Today, our researchers are involved in a very large and complicated program of germplasm development designed to support national bread wheat improvement activities around the globe. A broad genetic base is maintained in the CIMMYT materials for characters such as yield, wide adaptation, industrial quality, and disease resistance. Successful development of germplasm to fit these diverse objectives is a product of a well-planned crossing program, combined with the selection skill of breeders at CIMMYT and in the national programs who participate in the large international germplasm testing and development network.

Germplasm development

A trip to the bread wheat crossing blocks provides a vivid view both of the historical evolution and current scope of CIMMYT's bread wheat program. Hundreds of lines and varieties are included in these crossing blocks for use as potential parents in the breeding program. These lines are classified into subgroups on the basis of outstanding traits, e.g., resistance to specific diseases, yield potential, agronomic type, grain type, milling and baking quality, maturity, tolerance to soil and other environmental stresses, etc.

At present there are 15 subgroups in the spring wheat crossing block and 12 subgroups in the winter wheat crossing block. Included are materials with superior characteristics for highland areas, irrigated and rainfed areas, disease resistance, industrial quality, early maturity, soil stress problems such as

aluminum toxicity, and environmental problems such as extreme temperatures and moisture stress.

The composition of these crossing blocks and the total number of crosses made each year to solve various problems reflect the relative priorities of the CIMMYT bread wheat improvement program. Today, yield stability is given a higher relative priority in overall breeding objectives than higher yield potential, *per se*. A continuing strong emphasis is placed on disease resistance, particularly to the major rusts—stem rust, leaf rust, and stripe rust—which still constitute the major disease threat to stable yields in much of the developing world.

As CIMMYT has expanded its cooperation with scientists in different developing countries, the breeding program has been expanded to accommodate other disease problems. In particular, the fungal diseases of *Septoria* spp. have received considerably more research attention. More recently, materials with resistance to *Fusarium* spp., an important disease problem in central China and other areas with warm, humid climates, and *Helminthosporium* spp., also a disease problem in hotter production areas such as Bangladesh and Nepal's *tarai* area, have become part of the crossing program.

Other breeding priorities have been added to the crossing program as well. For example, the growing intensification of farming in many land-short developing countries, where two to three crops per year are desired, has led CIMMYT to place greater emphasis on developing early-maturity, high-yielding, disease-resistant varieties. The Indian variety Sonalika, with CIMMYT germplasm in its pedigree, is the most widely grown early maturity variety used in the developing world today, covering several million hectares in Nepal, Pakistan, India, and Bangladesh. It's availability and suitability for Bangladeshi wheat production conditions is perhaps the single most important factor explaining the expansion in wheat production over the last six years from 100,000 to 1 million tons. Unfortunately, it is rapidly becoming susceptible to new races of leaf rust, and replacement varieties are needed.

Growing land pressures have also been the motivating factor for CIMMYT's increased involvement in breeding for marginal lands with stress environments. Perhaps one billion people in developing countries live in marginal land areas in which agriculture is a highly precarious enterprise. The spring

x winter crossing program, which is developing materials with drought, cold, and possibly heat tolerance, and the aluminum toxicity tolerance work with Brazil are examples of varietal research which stand to benefit farmers in some of these more difficult production environments in the years ahead.

Rust resistance

Rust fungi are capable of mutation so that a wheat variety which had good rust resistance to the predominant races at the time of release may become susceptible to a new race within a relatively few years. A high yielding bread wheat variety which carries resistance to one or all of the three rusts rarely lasts more than 5 to 10 years before a new race overcomes its resistance.

All materials included in the CIMMYT international bread wheat screening nursery carry genes for rust resistance. In general, CIMMYT's advanced lines have very good levels of stem rust resistance. This resistance has held up over many years and seems to be approaching what breeders and pathologists call "durable resistance." The level of resistance to leaf and stripe rust in the CIMMYT materials does not, however, equal their stem rust resistance. Most released Mexican semidwarf wheats have lost their resistance to leaf and stripe rust within five years after widespread commercial production. A few varieties have remained disease resistant for decades, but their yield potential is less than present day varieties. For example, the tall Mexican variety Yaqui 50 has been resistant to stem rust for 25 years. Such varieties are used as parents in the crossing block to introduce stable resistance into advanced lines with high yield potential and other desirable agronomic traits.

Although resistance to leaf rust has not been stabilized to the extent achieved with stem rust, a few bread wheat varieties, such as the varieties Torim 73 and Pavon 76, have displayed an interesting resistance characteristic. Each became susceptible to leaf rust within two years after release, but the intensity of infection continued at low levels. This type of host parasite interaction is known as "slow rusting." It is characterized by low receptivity of the plant for the pathogen, a long latent period for the pathogen, and small

pustule formation. Leaf rust intensity over time is illustrated in Figure 1 for six of the most promising slow-rusting lines, as compared to the variety Inia 66, the susceptible check. Minivet"S", Car 422-Anahuac, Tanager"S" and Harrier"S" all have good levels of the slow-rusting character. Special

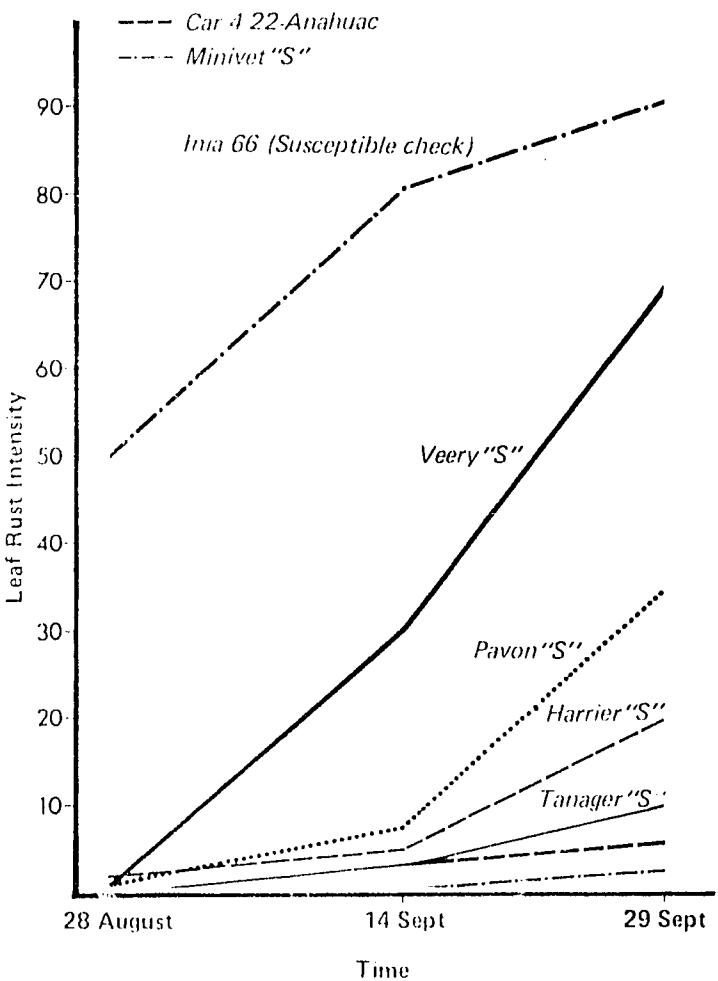


Figure 1. Slow rusting lines of bread wheat low leaf rust intensity over time compared to Inia 66 (susceptible check) at El Batan, 1980

attempts are being made to improve the durability of resistance to leaf rust by incorporating the slow-rusting characteristic of these cultivars into future bread wheat crosses.

Septoria resistance

An early criticism of the Mexican semidwarf wheats concerned the lack of sufficient resistance to *Septoria tritici,* which can reach epidemic proportions in many areas of the world—particularly in the rainfed wheat regions of North Africa and Argentina.

Soon after its inception, CIMMYT became involved in testing for septoria resistance. The International Septoria Observation Nursery (ISEPTON) was established and a cooperative program between Mexico and Israel was initiated to identify materials with resistance to septoria. A large number of lines with excellent resistance have been developed. Almost all of the most resistant lines have come out of our spring x winter crossing program. The varieties Kavkaz and Aurora, both from the Soviet Union, appear in the pedigrees of most resistant lines. Both varieties carry a small amount of rye genetic material, which probably accounts for their excellent resistance (triticale also exhibits excellent septoria resistance).

Spring x winter wheats

Since 1973, CIMMYT has been engaged in a cooperative research program with Oregon State University (OSU) to transfer useful genes between spring and winter habit wheats. In this cooperative program, CIMMYT is interested in developing spring wheats which contain winter wheat germplasm while OSU scientists are focusing their attention on the development of winter wheats which contain spring wheat germplasm.

In the CIMMYT portion of the program, the spring x winter lines developed from this project are consistently among the highest-yielding lines in recent international yield nurseries. Not only are these spring x winter lines higher-yielding than CIMMYT's best pure spring wheat lines, but they also have superior yield stability. CIMMYT's advanced line Veery"S" has been the top yield performer

in the last three international spring wheat yield nurseries (see Table 1). It also appears to possess better resistance to *Septoria tritici* and stripe rust, as well as better drought tolerance than do our best pure spring wheat lines.

Breeding for moisture stress conditions

Several years ago, our bread wheat breeders began to evaluate various spring x winter crosses for tolerance to

CIMMYT wheat agronomists are developing information useful to breeders in creating certain conditions for germplasm screening. One example is the assessment of water infiltration rates at the CIANO station to allow breeders to simulate desired moisture-stress conditions for germplasm screening.

Table 1. Average yield (kg/ha) of the top spring x winter variety Veery"S" compared to the high-yielding pure spring variety Nacozari across all locations reporting data from recent international spring wheat yield nurseries

	1978-79	1979-80	1980-81	$\bar{X}$
Veery "S"	4477	4339	4581	4465
Nacozari 76	4251	4126	4181	4186
Nursery mean	3778	3698	3789	3755

drought stress. These trials have indicated that some primary spring x winter lines have markedly better tolerance to drought than do our pure spring wheat materials. Some of the spring x winter lines are showing an impressive yield performance with only one auxiliary irrigation (following the irrigation for emergence) during the growing season. CIMMYT believes that these spring x winter materials offer considerable promise to improve yield dependability in spring wheat areas frequently confronted with drought stress problems.

Breeding for soil stress conditions

Since 1974, CIMMYT has been involved in a collaborative research program with three Brazilian institutions - EMBRAPA, FECOTRIGO, and OCEPAR - to develop high yielding, aluminum toxicity tolerant varieties. A shuttle breeding methodology is followed. Improvement criteria are designed to incorporate high yield, rust and septoria resistance, and semidwarf plant type into materials with tolerance to aluminum toxicity. In 1980, a new laboratory facility was added at El Batan to permit rapid preliminary screening for aluminum toxicity tolerance in relatively large amounts of breeding material. Progress in this project has been excellent. More than 50 crosses with a variable number of sister selections have been identified which have the sought after attributes of good plant type, rust and

septoria resistance, and aluminum toxicity tolerance. These lines, however, still require greater scab (fusarium) resistance before they can be released as varieties in Brazil.

In the process of looking for materials with tolerance to aluminum, we have also identified materials, such as the variety Alondra, which have a better capacity to take up phosphorus in soils with high P fixing tendencies. This uptake ability appears to be related to the fact that there are some rye chromosomes in this wheat material.

Cultivars for highland areas

Wheat productivity in the highlands of the Andes and East Africa has lagged behind the yield increases achieved in more favorable areas such as the irrigated plains of India and Mexico. Highland environments are often characterized by conditions conducive to high intensity disease development. Stem and stripe rust are the most common yield constraints, followed by septoria, fusarium, and other foliar pathogens. Although the total area planted to wheat in these highland areas appears small when compared to other production environments, wheat is still an important food source.

The CIMMYT bread wheat breeding program has limited its involvement in highland germplasm development to observation and classification of existing germplasm for further testing by national programs. These lines are being intensively screened for disease resistance by our regional staff operating in both the highlands of South America and East Africa. Currently, many advanced lines have been identified with resistance to septoria, *Fusarium nivale*, and the rust diseases.

Early-maturing wheats

An increasing number of wheat-producing areas are growing wheat within more intensive crop rotational patterns. For such areas, early maturity varieties with high yield could better fit into these production systems. More than 40 early-maturity lines have been identified with good disease resistance and are being distributed to cooperators interested in such material. Table 2 shows some of the best yielding, early-maturity advanced lines, as compared to the early var-

Table 2. Days-to-maturity of early-maturing advanced lines comparable in yield to the varieties Inia 66 and Sonalika, CIANO, Sonora, Mexico, 1980

Cross	Yield kg/ha	% of Sonalika
Ana x Kal-Bb	6204	109.1
Tsh "S"	6167	108.4
Inia 66 (check)	5991	105.1
HI666-Pvn "S"	5924	104.1
Maya-Pvn "S"	5921	104.1
(Vcm-Cno"S" x Cal/Nor-7c) Tanori 71	5886	103.5
(Cno-8156 x Tob-Cno/Jup) Plo	5798	101.9
Fury-Mo	5783	101.6
Cj-Cpr x Jup"S"	5711	100.4
Sonalika (check)	5688	100.0

ieties Sonalika and Inia 66, which are in commercial use today.

Wheats for warmer subtropical areas

A number of wheat-importing countries—notably Brazil, and those in Central America, West Africa, and parts of Asia—are interested in growing wheat in their winter season, the period of coolest temperatures and lowest humidity. Serious disease constraints are leaf blotch, caused by several forms of helminthosporium, and head scab, caused by fusarium. We are working to develop lines with resistance to *Helminthosporium sativum*. CIMMYT's preliminary work on helminthosporium, supported through a special project research grant from UNDP, has resulted in the identification of 210 advanced lines with varying degrees of resistance. These lines were distributed to national collaborators in 1980 through a special F_2 (early generation) nursery. Lines identified in this screening nursery are being used to constitute a

ERRATA

Table 2 on page 62 should read as follows:

Table 2. Early-maturing advanced lines comparable in yield to the varieties Inia 66 and Sonalika, CIANO, Sonora, Mexico, 1980*

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(Cno-8156 x Tob-Cno/Jup) Plo	5798	101.9
Fury-Mo	5783	101.6
Cj-Cpr x Jup"S"	5711	100.4
Sonalika (check)	5688	100.0

* Days to maturity at CIANO for all materials are from 115 to 120 days.

A number of wheat-importing countries situated in the subtropics are interested in growing wheat in their winter season, the period of coolest temperates and lowest humidity. Several serious disease and heat-stress problems exist for such production conditions. Work to develop wheats for these warmer subtropical conditions is being stepped up through a special project grant from UNDP.

new advanced-line screening nursery which will be distributed in 1982 to collaborators in helminthosporium-affected areas.

More recently, we have intensified our work on developing high-yielding lines with resistance to head scab caused by *Fusarium* spp. Some 90 CIMMYT bread wheat lines have been identified which possess some resistance. Often, however, this resistance breaks down under severe disease conditions. Consequently, there is a need to pyramid the different genetic sources of resistance to this disease. New materials from China and Brazil with some resistance to fusarium have been supplied to CIMMYT and are being used in the crossing program. A shuttle breeding program is being planned between CIMMYT and Argentina (Brazil and China may also participate in this arrangement).

Expanded efforts are also under way to develop more heat-tolerant materials for areas such as the Sudan, Bangladesh, and parts of India. In this work, our breeders are looking to some of the spring x winter lines for vernalization traits which will allow the materials in heat prone areas to tiller more profusely under high temperatures.

International testing

In 1981, ten different types of bread wheat nurseries were distributed at the requests of collaborators in about 100 countries. In addition, CIMMYT frequently filled requests for specific materials made by individual scientists around the world.

1981 Bread wheat nurseries	Lines/ varieties	Sets
Early Generation Materials		
F_2 Irrigated	357	50
F_2 Dryland	298	55
F_2 Septoria	73	30
F_2 Early	57	55
F_2 Aluminum	92	25
F_2 Spring x Winter	347	80
15th IBWSN - International Bread Wheat Screening Nursery	206	150
18th ISWYN - International Spring Wheat Yield Nursery	50	100
3rd ESWYT - Elite Spring Wheat Yield Nursery	30	30
12th ISEPTON - International Septoria Observation Nursery	180	60

Varietal releases

It is the responsibility of national programs to name and release new varieties. CIMMYT, therefore, has only partial information on the release around the world of bread wheat varieties which carry CIMMYT distributed germplasm in their pedigrees. During 1980-82, however, we had reports from 12

Selected bread wheat varieties bred by CIMMYT-INIA or predecessor organizations, and released in Mexico, 1950-81

Year of Mexican release	Variety name	Year of cross	Yield potential kg/ha*	Plant ht cm	Grain color	Disease rating in Mexico** Stem rust	Leaf rust	Stripe rust	Septoria
1950	Yaqui 50	1945	3500	115	Red	TMS	20MS	10MS	MR
1960	Nainari 60	1958	4000	110	Red	10MS	5R	0	
1962	Pitic 62	1956	5870	105	Red	100S	60S	80S	MR
1962	Penjamo 62	1956	5870	100	Red	50MS	0	80S	MR
1964	Sonora 64	1957	5580	85	Red	20MS	70S	80S	S
1964	Lerma Rojo 64	1958	6000	100	Red	30MR	80S	80S	S
1966	INIA 66	1962	7000	100	Red	5MR	100S	80S	S
1966	Siete Cerros 66	1957	7000	100	Amber	TMS	60S	100S	S
1970	Yecora 70	1966	7500	75	Amber	TR	100S	100S	S
1971	Cajeme 71	1966	7000	75	Red	TR	100S	100S	S
1971	Tanori 71	1968	7000	90	Red	20MR	80S	60S	S
1973	Jupateco 73	1969	7500	95	Red	TMR	80S	60S	S
1973	Torim 73	1967	7000	75	Amber	TMR	20MS	40S	S
1975	Cocoraque 75	1969	7000	90	Red	TR	TR	20MR	S
1975	Salamanca 75	1967	7000	90	Red	TMR	20MS	20MS	S
1975	Zaragoza 75	1964	8000	90	Red	0	30MS	80S	S
1976	Nacozari 76	1969	8000***	90	Amber	0	TMR	10MR	S
1976	Pavon 76	1970	8000***	100	Amber	0	TMR	10MR	MS
1977	Pima 77	1964	7500	90	Amber	5MR	TMR	30MS-MS	S
1977	Hermosillo 77	1972	7500	85	Red	5MR	5MR	TR	S
1977	Jauhara 77	1969	8000***	90	Red	5MR	TR	TR	S
1979	CIANO 79	1974	8000***	90	Red	TR	TR	TR	S
1979	Imuris 79	1974	8000***	90	Amber	TR	TR	TR	S
1979	Tesia 79	1974	7500	90	Red	TR	TR	TR	S
1981	Glennson S81	1975	8000***	85	Red	TR	TMR	TR	MR
1981	Genaro S81	1975	8000***	90	Red	TR	TMR	TR	MR
1981	Ures S81	1975	8000***	85	Red	TR	TR	TR	MR
1981	Tonichi S81	1974	8000***	90	White	TR	TR	TR	S
1981	Sonoita S81	1974	7500	65	White	TR	TR	TR	S

* Measured at experiment station in Mexico, irrigated under high soil fertility and essentially disease-free

** All varieties were resistant to all three rusts under Mexican conditions at time of release. R - resistant; S - susceptible; O - no rust; MR - moderately resistant; MS - moderately susceptible; 20MS - moderately susceptible type lesion on 20 per cent of plant surface, balance of surface is lesion-free; TMS - moderately susceptible type lesion in trace amount, balance is lesion-free; TR - resistant type lesion present in trace amount, balance is lesion-free

*** Yield of varieties released in 1976-81 has ranged between 7500-9500 kg/ha in different seasons and trials. A conservative minimum of 8000 kg/ha is given here for these recent releases

countries on the release of 43 new varieties carrying CIMMYT germplasm.

Argentina (3)	Portugal (3)
Bolivia (2)	Spain (9)
Brazil (3)	Tanzania (3)
Mexico (11)	Tunisia (2)
New Zealand (1)	Turkey (3)
Pakistan (1)	Zambia (2)

DURUM WHEAT

Durum wheat is used in making pasta products and certain types of unleavened bread. Worldwide, this wheat species is grown on about 30 million hectares. The most important production areas are found in the Mediterranean region, the Mideast, Argentina, Chile, USSR, Canada, and the USA. Developing countries grow durum wheats on about 11 million hectares. Most of the developing country durum area is rainfed and commercial yields are quite low. Major biological production constraints are environmental stresses, such as temperature and moisture, and disease problems, particularly stem and leaf rust, septoria, and powdery mildew.

CIMMYT's current durum crossing program places a heavy emphasis on disease resistance and industrial quality. In recent years, drought and cold tolerance, insect resistance (mainly to sawflies), and early maturity have also received increased research attention. Given the already high yield potential of CIMMYT durum materials, efforts to push maximum yield potential higher, while still continuing, have a lower priority than was the case in earlier years of our improvement work. Rather, the major emphasis is on yield dependability.

Yield potential

Yield data from the first 10 International Durum Yield Nurseries (IDYN), which included both tall and

semidwarf cultivars and durum lines developed by CIMMYT and other breeding programs around the world, show a steady increase in the average nursery yield mean from 2965 to 3577 kg/ha, a gain of 17 percent over the 10-year period.

Today, some of CIMMYT's advanced durum lines yield above 8 t/ha in northwest Mexico (see Table 3). Results of recent international trials, the 11th (1979-80) and the 12th IDYN (1980-81), showed that a number of CIMMYT durum lines had average yields across all locations of around 4.5 t/ha. In particular, the advanced lines Yavaros"S", Frigate "S", Cormorant"S", and Mallard"S" were all high and stable yielders.

An increasing number of early-maturity lines with good disease resistance are also being developed. One of the best lines is comparable in maturity to the early-maturity variety Mexicali 75, yet is yielding up to 1.3 t/ha more (see Table 3).

Resistance to diseases

The development of durum lines with good stripe rust resistance has been quite successful. Higher levels of resistance to leaf rust and stem rust, *Septoria nodorum, Septoria tritici, Helminthosporium* spp., and *Fusarium* spp. are still needed, since high levels of susceptibility to these

Table 3. Yield performance and days to flower of advanced durum lines compared to recent standard cultivars (checks) at CIANO, Sonora, Mexico, 1980-81

Cross or Variety	Yield kg/ha	Days-to-flower
(Mexi 75-Chumpi 2 x Fab"S"/P66.270) Goose"S"	8049	75
Gull"S"-Snipe"S" x Gdo VZ4498017	8017	79
Shwa"S"-Mexi 75 x Yav"S"	7917	76
Yavaros"S"	7834	76
Frig"S"-Ren"S" x Ruff"S"-Gta"S"/ Ren"S"	7508	66
Yavaros 79 (check)	7495	77
Mexicali 75 (check)	6229	66

diseases are still recorded at this time in many developing country durum wheat areas.

In 1981, we began to assemble a new F_2 group of stem rust resistant materials using germplasm from Ethiopia, the USA, and Canada, along with other materials identified in the CIMMYT screening nurseries which have been planted in stem rust areas in recent years. Similarly, we have increased our efforts to assemble more materials with resistance to *Septoria* spp. and *Helminthosporium* spp.

Improvement in agronomic characteristics

Work continues to incorporate added drought tolerance into durums, mainly using materials from India and the USSR. Early-maturity durum lines such as Cocorit 71, Mexicali 75, and others appear promising for drought-prone areas, mainly because they can provide the farmer with a margin of drought escape. Improvements in other agronomic traits such as cold tolerance (using materials mainly from Turkey), straw strength, and materials of different heights for irrigated and rainfed production environments are also being pursued in the program. A new F_2 nursery is being assembled with materials of a medium-to-tall stature for hilly areas characterized by limited management, high weed competition, and shallow soils.

Efforts continued in the modification of the head architecture in the durum plant to increase yield potential and to permit faster drying in durums after rain and mist, thus reducing conditions that foster the incidence of head-rotting diseases. Progress has been made in developing long-lax and semi-lax heads with greater spacing between spikelets, traits which reduce the incidence of these disease problems.

Finally, work continued to develop solid stem durum wheat varieties for areas in North Africa where sawfies can cause serious yield reductions in normal semidwarf materials. A group of tall local varieties from North Africa with solid stems are being crossed with high-yielding, early-maturing semidwarf varieties. Materials are now available which combine the solid stem character into high yielding semidwarf lines with early-to-intermediate maturity characteristics.

Industrial quality

Although most of the developing world's durum wheat production is used for home consumption, a number of

Durum wheats are grown on approximately 12 million hectares in the developing world. The yield potential of CIMMYT's durum germplasm continues to rise and is now similar to, or greater than, the yield levels of our best bread wheats. Greater resistance to certain diseases is still needed in CIMMYT's durum materials.

developing countries are in a position to produce durums for export to Europe and other regions interested in producing semolina (durum flour) to make macaroni and other pasta

products. To be readily marketable, these durum wheats must have large size grains, high grain test weights, acceptable pigment and protein content, and medium-to-strong gluten strength.

CIMMYT's cereal quality laboratory staff routinely screens new high-yielding lines to identify materials which maintain quality characteristics during macaroni processing. Numerous lines of satisfactory quality and good yield potential are included each year in the IDSN and EDYT nurseries distributed to durum-growing countries. Superior materials identified in this testing network are selected and recycled into the durum crossing program to increase the percentage of lines with good quality characteristics among the CIMMYT materials.

International testing

In 1981, CIMMYT distributed seven different durum nurseries to collaborators in 62 countries.

1981 Durum wheat nurseries	Lines/ varieties	Sets
Early Generation Materials		
F_2 Irrigated	217	35
F_2 Dryland	432	40
F_2 Cold Tolerant	124	40
CB–Crossing Block	318	30
13th IDSN–International Durum Screening Nursery	235	70
13th IDYN–International Durum Yield Nursery	30	70
EDYT–Elite Durum Yield Trial	30	40

Varietal releases

During 1980-81, we had reports from six countries of the release of 13 new durum varieties which carried CIMMYT germplasm in their pedigrees.

Cyprus (1)	Portugal (3)
Ethiopia (2)	Tunisia (2)
India (3)	Turkey (2)

Selected durum wheat varieties bred by CIMMYT-INIA, or predecessor organizations, and released in Mexico between 1960-81

Year of Mexican release	Variety name	Year of cross	Yield potential* kg/ha	Plant ht.* cm	Disease rating in Mexico** Stem rust	Leaf rust	Stripe rust	Test weight kg/hl	*** Pigment ppm
1960	Tehuacan 60	1954	4200	150	0	10MR	20MS	81	5.5
1965	Oviachic 65	1960	7000	90	0-40MS	30S	5MR	81	7.2
1967	Chapala 67	1961	7000	85	0	10MS	10MR	83	4.0
1969	Jori C 69	1963	7700	85	0	TR	5MS	81	3.7
1971	Cocorit 71	1965	8300	85	0	5MR	5MS	81	3.6
1975	Mexicali 75	1969	8600	90	0	TR	5MR	80	5.8
1979	Yavaros C79	1970	8600	90	0	TR	TR	83	5.0

* Measured at CIANO experiment station, under good agronomic practices

** In Mexico, at time of release. R - resistant; MR - moderately resistant; MS - moderately susceptible; S - susceptible. Figures before letters indicate percentage of infection

*** Carotinoids

TRITICALE

Triticale is a man-made cereal. It results from a cross between wheat and rye. Although the cross was demonstrated by British scientists over 100 years ago, it was not until the 1950s that researchers in Europe and North America began intensive efforts to transform triticale into a commercial crop. CIMMYT's work on triticale dates back some 18 years and today represents one of the largest triticale improvement programs in the world. The progress in developing triticale as a commercial crop has been a remarkable research achievement. Ten years ago, the yield of the best triticales was half that of the best bread wheat; today, they are equal. Problems of lodging and inferior grain quality have been overcome to a considerable extent, but problems still remain. Grain quality must still be improved. Shorter and earlier-maturity materials with high-yield potential are still needed for many areas with the potential for triticale production. Greater dormancy is needed to prevent grain sprouting in the head before harvest. Finally, disease resistance which generally has been exceptionally good in triticales must be maintained and/or strengthened.

Triticale is grown on about 500,000 hectares around the world. Hungary, the USSR, Australia, Canada, the USA, South Africa, Argentina, Kenya, Mexico, China, and Spain all grow triticale commercially. Other countries, such as Brazil, Chile, India, Tanzania, and Portugal, are becoming increasingly involved in triticale research and in promoting more national production.

Yield and adaptation

At present, triticales are competitive in yield with wheat (see Table 6). In certain production areas, such as those with acid soils, in semi-tropical highlands, and in some specific disease areas, triticale generally shows better adaptation and yield performance than wheat. Areas where triticale has shown significant yield advantages over wheat are the Himalayan foothills, East Africa, the central high plateau of Mexico, the Andean region, Brazil, and parts of Europe and Australia.

Table 6. Highest yielding lines from the 12th ITYN (1980-81) (average from 35 locations)

Variety or cross	Yield kg/ha	Test weight* kg/hl
Juanillo 97	4179	68
Beagle	3914	65
RAM "S"	3871	63
M_2A	3859	67
Muskox "S"	3763	69
Caborra-79 (check)	3707	66
Cananea-79 (check)	3702	64
Nacozari 76 (bread wheat check)	3364	75

* Average test weights of 70 kg/hl are considered excellent for triticale

Early maturity

Although triticale strains generally flower as early as wheat they mature more slowly, making them too long in season for some potential production areas. Efforts to develop earlier maturity types are progressing quite satisfactorily. Triticale lines which flower slightly ahead of

the early-maturity bread wheat variety Sonalika have now been identified. These lines are by far the earliest triticale strains found to date and appear to be well-suited to such areas as the high plateau of Mexico, where early maturity is a needed varietal characteristic. In addition to selecting for earliness among our triticale germplasm, *per se*, we also have initiated breeding work on ryes used to produce primary triticales. We are seeking to identify and/or develop light-insensitive, early-maturity ryes to use in future triticale crosses, since the rye parent may be the cause of the relative lateness of triticales.

Preharvest grain sprouting in the head is another factor delaying the acceptance of triticales in areas where the conditions at harvest time are moist. Some improvements in tolerance to preharvest sprouting have been made, but a higher level is still needed. The most promising sources of resistance to sprouting appear to be winter type triticales, some spring triticales developed in Brazil, and some ryes recently developed in northern Europe. These materials are being crossed with CIMMYT's high-yielding triticale lines to incorporate resistance to preharvest sprouting throughout our germplasm.

Seed type and test weight

The industrial quality of CIMMYT's first triticales was rather poor. The milling performance was unsatisfactory and flour yields were low compared to bread wheats. These low flour yields were associated with grain shriveling which resulted in low grain test weights (kg weight of grains per hectoliter).

Today, improved test weight is a central objective of the CIMMYT triticale improvement program. It has been relatively easy to find triticales that produce higher test weights under the most favorable production environments, such as at the CIANO station in Sonora, Mexico. As production conditions become less favorable, however, the grain test weights of most current triticale lines drop sharply. Our Toluca station is proving to be a good site to identify lines which show relatively high and stable test weights across many locations.

Recent data on test weights show a number of triticale lines with acceptable and stable test weights within 90 percent of the bread wheat variety Pavon 76 (considered a

good check variety in this regard). Through 1981, only two countries (USA and Canada) have set milling industry standards for triticale test weights at 70 kg/hl. Numerous CIMMYT lines meet this standard. While CIMMYT supports the setting of standards, we do not think that triticale must produce a grain identical to wheat (with equally high test weights) to take its place among the important small grain cereals of the world.

Disease resistance

Triticales continue to demonstrate very high levels of resistance to the three rusts, septoria, several smuts, and powdery mildew. Some of the minor wheat diseases have been more of a problem for triticales. Bacterial blights often cause damage, and heavy attacks of head scab have occurred in certain areas of Africa. However, in general triticale has had few problems with disease, at least to date.

Widening the germplasm base

We continue to introduce more genetic variation into materials in the triticale program by producing new primary triticales and through introductions from other triticale programs around the world. Most materials in the CIMMYT triticale program are durum wheat x rye crosses (hexaploid triticales) although CIMMYT also makes some bread wheat x rye crosses (octoploid triticales). However, until 1978 the bread wheat x rye crosses were used for improving the hexaploid triticales. Since 1978, we have started to look at the potential of bread wheat x rye crosses as a means to improve the seed quality in triticale. The work with bread wheat x rye triticales is too new to provide definitive data, although reports from China indicate that these triticales may have considerable promise.

We are particularly interested in using improved rye germplasm in our crossing program, especially the early and dwarf ryes, and have initiated a modest rye improvement program.

We are also using winter-type triticales from programs in Europe and North America in crosses with spring types. These spring x winter crosses have been very useful in selecting forage-type triticales.

Industrial quality

Most of the food products made from wheat flour have been made successfully from pure triticale flour, including fermented and non-fermented dough products. For fermented doughs, where higher levels of gluten are critical, triticales lack the bread-making qualities of bread wheats. For non-fermented dough products, such as *Chappatis* and unleavened bread, triticale flour and wheat flour are of equal utility.

The number of CIMMYT triticale lines found to produce acceptable flour yields and loaf volume has increased

Recent research efforts have resulted in significant improvements in grain quality in CIMMYT's high-yielding triticale materials. Efforts to develop earlier-maturing triticale types are also showing considerable progress.

substantially. It has also been found that flour yields in triticales with harder grain may be improved by 15 percent by tempering the triticale grain before milling as if it were a hard wheat.

Triticale has also been used very successfully in mixtures with wheat flour. In mixtures of up to 75 percent triticale flour and 25 percent wheat flour, good quality bread can be made. It has been observed that triticale flour sometimes acts in a synergestic manner when added to wheat flour, and the mix of the two flours gives a better product than either used alone. In some cases, the loaf volume of bread made with triticale-wheat flour mixtures is higher than the loaf with 100 percent wheat flour.

CIMMYT scientists are confident that triticale grain quality characteristics can be further improved through breeding, and that the grain's utility can be enhanced through minor modifications in milling and baking technology. In the early years of triticale improvement at CIMMYT, lines with poor industrial quality were often retained because of superior agronomic characterisitcs. Today, much more selection pressure is being placed on quality characterisitcs since most of the agronomic problems originally associated with triticales have been overcome.

International testing

In 1981, five different triticale nurseries were distributed upon request to collaborators in 84 countries.

1981 Triticale nurseries	Lines/ varieties	Sets
Early Generation Materials		
F_2 Irrigated	244	35
F_2 Dryland	255	47
F_2 Spring x Winter	70	70
13th ITSN–International Triticale Screening Nursery	172	100
13th ITYN–International Triticale Yield Nursery	50	90

Varietal releases

CIMMYT has received reports from nine countries of the release of 32 new triticale varieties over the last four years.

Australia (11)	Mexico (2)
Bulgaria (1)	Spain (2)
Canada (3)	Portugal (7)
Hungary (1)	USA (4)
Italy (1)	

BARLEY

In 1972, CIMMYT began work on the improvement of barley for use as a human food. Today, this barley improvement program is conducted in collaboration with ICARDA. Until 1979, CIMMYT's barley scientists were largely involved in the generation of germplasm with high-yield potential, lodging resistance, wide adaptation, hull-less grain, and high nutritional quality. Substantial progress has been made in all these research areas. We now have a number of high-yielding semidwarf hulled and hull-less barley lines (see Table 4).

The primary problem with the CIMMYT advanced line barley materials is that many of them are highly susceptible to diseases, in particular barley leaf rust, stripe rust, *Rynchosporium secalis* (scald), *Helminthosporium* spp., and barley yellow dwarf virus. Major emphasis is now being given to the development of greater disease resistance in CIMMYT's germplasm. In addition, more intensive use of winter barley germplasm is being used in spring x winter crosses to develop high-yielding barleys for production areas with long seasons.

Disease resistance

A shuttle breeding program between Mexico and the Andean zone regional staff has been initiated to speed up the development of germplasm with resistance to barley leaf rust, stripe rust, scald, and barley yellow dwarf virus. Materials which have shown resistance have been added to a special crossing block for disease research. A total of 372 entries with resistance have been assembled and these are being used extensively in the crossing program.

During the 1981 summer cycle at El Batan, artificial epidemics were created for both barley leaf rust and *Rhynchosporium secalis* (scald). A number of lines were identified with resistance to one or both diseases.

Hull-less grain

Hull-less (naked) barley has several advantages as a human food. The edible dry matter is greater in the hull-less type and more of the vitamins and minerals are retained than lost as is the case with the hulled types when the grain must be pearled (peeled). Finally, hull-less grain threshes more easily and can be eaten immediately after threshing.

Through crosses to Godiva, a hull-less variety from the USA, and other naked types, about 40 percent of the CIMMYT barley materials have the hull-less character. A number of advanced hull-less lines now have a yield potential above 5 t/ha (see Table 4). These materials still require improvement for grain size, plumpness, and resistance to germ damage during threshing. In addition, higher levels of disease resistance are still needed before such lines can become varieties in most barley-producing areas.

Table 4. Comparative yields of hulled and hull-less barley lines from trials at CIANO, Sonora, Mexico, 1980-81

Variety or cross	Yield kg/ha	Days to maturity
Hulled		
Min 480-Gva x 11012-Tern	6614	121
DL 69-Bahtim 10 x H251	6100	108
C13909.2 x M66.151-Manker (Apm-1B65/Api-CM67 x Ds-Apro)	5941	120
Hull-less		
Ore"S" x Emir-Nackta, Ast 9071	5356	130
CM67-Gva x Api-EB 489.8.2.15.4[Cal. Mr x Ds-Apro(Pro-Tol 1 x Cer^2-Tol I/5106)]	5264	127
BDGC-Gas(Apm-1B65 x 11012.2/Api-CM67 x Ds-Apro)	5349	120
America (Hull-less barley check)	2453	125

CIMMYT barley materials have been considerably improved for plant type and straw strength, have added earliness, and a semidwarf plant architecture. A range of hulled (6 7 t/ha) and hull less (5 6 t/ha) grain types have been developed that are suitable for many barley growing locations. The major breeding priority now is to improve disease resistance in CIMMYT's barley materials.

Early maturity

In many areas of the world with low moisture or short-season environments, quick maturing barley is one of the few cereals which will produce grain. For the last five years, our breeders have been seeking varieties which mature 20 to 30 days earlier than existing commercial varieties and still produce acceptable yields. Table 5 shows a number of early varieties which mature in about 90 days and yield in the

3 to 4 t/ha range. These early barleys should prove to be valuable for farmers located in the more marginal cereal-producing environments.

Table 5. Comparative yields of early-maturing barley lines from trials at CIANO, Sonora, 1980-81

Variety or cross	Yield kg/ha	Days to maturity
Hulled		
Mona-Gateway 63 x BI	4355	90
Mona x Mzq-DL 71	4157	88
Mona (Early hulled check)	3732	95
Hull-less		
Mari-Coho x Sultan-Nacta	3100	94
Amp-RL x Bco. Mr-Gva	3814	88
Mona (Early hulled check)	3168	95

Spring x winter crosses

Some barley-producing areas, such as those found in the Mediterranean countries, need long-season varieties. Our barley spring x winter crossing program offers new germplasm prospects for these production areas. In 1981, for the second time, spring x winter F_2 materials were sent to 50 locations having long growing cycles. Observations of these materials showed that the spring x winter lines were far superior in adaptation and yielding ability when compared to straight spring x spring materials.

Nutritional quality

Improvement of the nutritional value of the barley crop has received major emphasis in the CIMMYT program. With the addition of the high-lysine gene from the variety Hiproly, several advanced lines have been developed which have considerably higher total protein and protein quality levels than are normally found in barley. Eighty-eight of these protein quality lines were included in a special crossing block distributed in 1981 to scientists in 25 countries. Work to improve the protein quality of barley is being continued, but at a low priority level.

Industrial quality

Some hull-less barley lines have been identified that make flour suitable for mixing with wheat flour of good baking quality to make acceptable bread. Such mixtures (20%/o barley, 80%/o wheat) may serve countries where barley can be produced more successfully than wheat, and where increasing quantities of wheat are being imported for bread making.

International testing

The number of countries requesting barley nurseries in 1981 again increased over the previous year. Eight different nurseries were distributed to collaborators in 79 countries.

1981 Barley nurseries	Lines/ varieties	Sets
Early Generation Materials		
F_2 Spring x Spring	371	40
F_2 Spring x Winter	270	50
F_2 Andean Zone	370	20
CB–Crossing Block (Normal)	402	40
CB–Crossing Block (Nutritional Quality)	88	25
CB–Crossing Block (Disease Resistance)	158	50
9th IBON–International Barley Observation Nursery	348	100
4th IBYT–International Barley Yield Trial	50	85

INTERNATIONAL TESTING

In 1981, collaborating scientists in 103 countries requested 1,771 trials of wheat, triticale, and barley from 30 different CIMMYT wheat program nurseries. Each nursery consists of a set of varieties, lines or populations–sometimes as many as 600 entries–which are constituted to assist in solving various breeding requirements and particular disease problems. In recent years, CIMMYT has received more requests for early generation (F_2) materials and, when possible, has shared its segregating germplasm with scientists around the world. In addition, several regional nurseries–mainly used for disease screening and surveillance–have been operating in North Africa, the Middle East (in collaboration with

ICARDA), parts of Asia, in South America, and in Sub-Sahara Africa. (These nurseries are discussed under the regional programs section.)

National program collaborators are free to use any of the materials included in a nursery. When material from the international nurseries is released as a commercial variety in a particular country, CIMMYT requests that the origin of the germplasm be recognized. Further, varieties originating from CIMMYT germplasm are not protected by patents or plant breeders' rights.

The most widely distributed international nurseries of CIMMYT are the international screening and yield nurseries.

International screening nurseries

These nurseries include CIMMYT's most advanced lines, and are grown in double rows for observation and evaluation.

The objectives of these nurseries are:

(1) To provide cooperating scientists with an opportunity to assess the performance of new advanced lines being developed in CIMMYT's wheat, triticale, and barley breeding programs.

(2) To supply cooperators and CIMMYT scientists with information on the performance of new materials under a wide range of climatic and disease conditions.

(3) To release sources of genetic variability which cooperators may use directly or in crosses with their own materials.

International yield nurseries

Yield nurseries differ from screening nurseries in that the materials tested are grown in replicated yield trials. The objectives of these nurseries are:

(1) To provide research workers developing new varieties with an opportunity to assess the performance of their advanced breeding lines over a wide range of climatic, cultural, and disease conditions.

(2) To serve as a source of fundamental information on adaptation.

(3) To allow local research and extension workers to compare the performance of new varieties from many countries.

(4) To provide cooperators with new sources of genetic variability which may be used directly for varietal release or as parents for new crosses.

Bread wheat, durum, triticale and barley nurseries distributed by the international nurseries program in 1981

	Bread wheat	Durum	Triticale	Barley
Latin America	185	79	79	95
Argentina	26	20	8	6
Bolivia	12	12	6	9
Brazil	29	4	18	7
Chile	22	9	7	9
Colombia	7	–	1	9
Costa Rica	2	2	2	2
Dominican Republic	1	–	1	3
Ecuador	13	8	6	10
Guatemala	3	–	1	–
Guyana	3	–	2	–
Mexico	32	11	18	16
Nicaragua	2	–	1	–
Paraguay	6	–	2	1
Peru	20	13	5	22
Uruguay	4	–	–	–
Venezuela	3	–	1	1
Africa	130	72	69	85
Algeria	10	11	5	9
Angola	1	1	1	1
Botswana	2	–	2	–
Burundi	2	–	1	–
Cameroon	5	–	4	2
Centr. Afr. Rep.	1	–	1	–
Egypt	5	6	5	7
Ethiopia	10	10	3	12
Ghana	1	–	–	2
Kenya	12	7	5	6
Liberia	1	1	2	1
Libya	2	2	–	2
Malawi	5	–	2	1
Mali	1	1	–	–
Morocco	8	6	2	8
Mozambique	2	1	2	2
Niger	1	–	–	1
Nigeria	3	3	2	3
Rwanda	4	2	2	–
Senegal	2	–	–	–
Somalia	2	3	–	3
South Africa	12	7	11	9
Sudan	8	1	4	3
Tanzania	5	–	2	2
Tunisia	9	8	5	9
Uganda	3	1	1	1
Upper Volta	1	–	1	1
Zaire	1	–	1	–
Zambia	7	–	4	–
Zimbabwe	4	1	1	–
Mideast	76	52	30	48
Cyprus	2	4	3	6
Iran	7	2	2	3
Iraq	1	1	–	2
Israel	14	6	2	5
Jordan	6	7	1	6
Lebanon	4	3	1	2
Quatar	1	–	1	1
Saudi Arabia	4	–	–	–
Syria	22	16	12	12
Turkey	13	13	7	10
Yemen	2	–	1	–

	Bread wheat	Durum	Triticale	Barley
Asia	91	23	39	68
Afghanistan	5	3	1	2
Bangladesh	9	1	1	4
Bhutan	1	–	–	2
Burma	4	–	2	–
China	15	2	3	7
India	12	7	7	14
Indonesia	1	1	1	1
Japan	1	–	–	–
Korea, North	–	–	–	2
Korea, South	2	–	2	10
Nepal	5	–	2	2
Pakistan	20	5	6	11
Philippines	7	–	7	2
Sri Lanka	–	–	–	1
Taiwan	–	–	1	3
Thailand	7	4	5	5
Vietnam	2	–	1	2
Oceania	13	7	11	3
Australia	7	4	6	1
New Zealand	6	3	5	2
Europe	113	86	80	78
Albania	6	4	4	1
Austria	–	1	–	1
Belgium	1	–	1	–
Bulgaria	–	1	3	–
Czechoslovakia	3	1	–	–
England	7	–	–	2
Finland	2	–	–	1
France	8	5	6	8
German D. Rep.	–	–	1	–
Germany, F. Rep.	1	3	2	1
Greece	7	6	3	5
Hungary	4	5	4	–
Ireland	2	–	–	–
Italy	6	17	10	11
Malta	–	4	–	6
Netherlands	–	–	–	2
Norway	3	–	2	4
Poland	5	1	–	4
Portugal	9	6	5	5
Rumania	8	4	7	7
Spain	25	17	14	14
Sweden	5	1	3	–
Switzerland	–	–	2	–
USSR	5	4	4	1
Yugoslavia	6	6	2	5
North America	67	23	42	27
Canada	20	9	16	12
USA	47	14	26	15
TOTALS:				
Countries	94	62	84	79
Locations	675	342	350	404

WIDE CROSSES

During 1981 this unit continued its research efforts to incorporate disease and environmental stress tolerance characteristics from other genera into wheat. The alien genera were comprised of several species of *Aegilops, Agropyron, Elymus, Haynaldia, Hordeum, Secale,* and *T. turgidum.* The methodology involves developing alien addition lines, substitution lines, and attaining subtle alien gene transfers through irradiation or genetic manipulation.

Some *Aegilops* species have genes for rust resistance and salt tolerance. *Agropyron* species possess genes for rust resistance, salt tolerance and barley yellow dwarf resistance. Some *Elymus* species of the 2n=4X=28JJXX group, (*E. giganteus*) have shown excellent drought, salt, cold and heat tolerance, as well as resistance to leaf-spotting diseases. *Agropyron* and *Elymus* species are also being screened for genes conveying fusarium and helminthosporium resistance.

Several hybrids have been produced and verified as hybrids on the basis of their F_1 chromosome number. A total of 54 hybrid combinations are maintained in El Batan, CIMMYT, under greenhouse conditions. All hybrids are self-sterile but have produced backcross seed with relative ease compared to obtaining fertile doubled plants following colchicine treatment. The combinations receiving greater emphasis are as follows:

Wheat x Elymus giganteus

E. giganteus (2n=28) is an Asian grass that is tolerant of soil and environmental stresses, and is virtually free of all leaf-spotting diseases. It has been hybridized with wheat, and the hybrid, when pollinated by wheat, has produced BC_I progeny. The second backcross (wheat—*E. giganteus*—wheat x wheat) produced BC_{II} progenies that were partially self-fertile and set from 35 to 80 percent BC_{III} seed when backcrossed to wheat. BC_{IV} progenies were produced in 1981 and cytological studies are proceeding to identify the individual *Elymus* chromosomes that were added to wheat. Some of the progenies have expressed resistance characteristics associated with leaf rust, stem rust, and helminthosporium.

CIMMYT's expanded wide cross efforts are aimed at the transfer of useful genes from related genera into wheat to improve tolerance to environmental extremes and to increase disease resistance. With the addition in 1980 of an experienced cytologist to the staff, considerable progress is being made to develop techniques and procedures to successfully cross wheat to other genera and obtain fertile progenies.

Wheat x Agropyron hybrids

Agropyron elongatum (2n=70), *A. distichum* (2n=28), and *A. junceum* (2n=42) are salt-tolerant species, although the genetic mechanism for tolerance has not been identified. Hybrids of *A. elongatum* with durum and bread wheat varieties have been made and shall be analyzed for their tolerance responses after desirable plants are selected from the advanced backcross generations. The material is currently in BC_{II} generation. *A. distichum* has been hybridized by Dr. Pienaar (South Africa) with durum and bread wheat. CIMMYT received amphiploid and BC_I seeds of these hybrids as part of a germplasm exchange agreement. We are continuing our efforts

to introduce other wheat germplasm into the advanced BC progenies derived from (*T. aestivum* cv. Inia—*A. distichum*) x Inia. The purpose is to develop 'addition' lines and to test ultimately for salt tolerance. BC_I selfed or BC_{II} progenies have been obtained following selections for leaf rust, stem rust, and agronomic plant characteristics. Hybrids of *A. junceum* with *T. aestivum* are cytologically highly complex, and progenies in BC_{II} express poor self-fertilitly.

SPECIAL GERMPLASM DEVELOPMENT

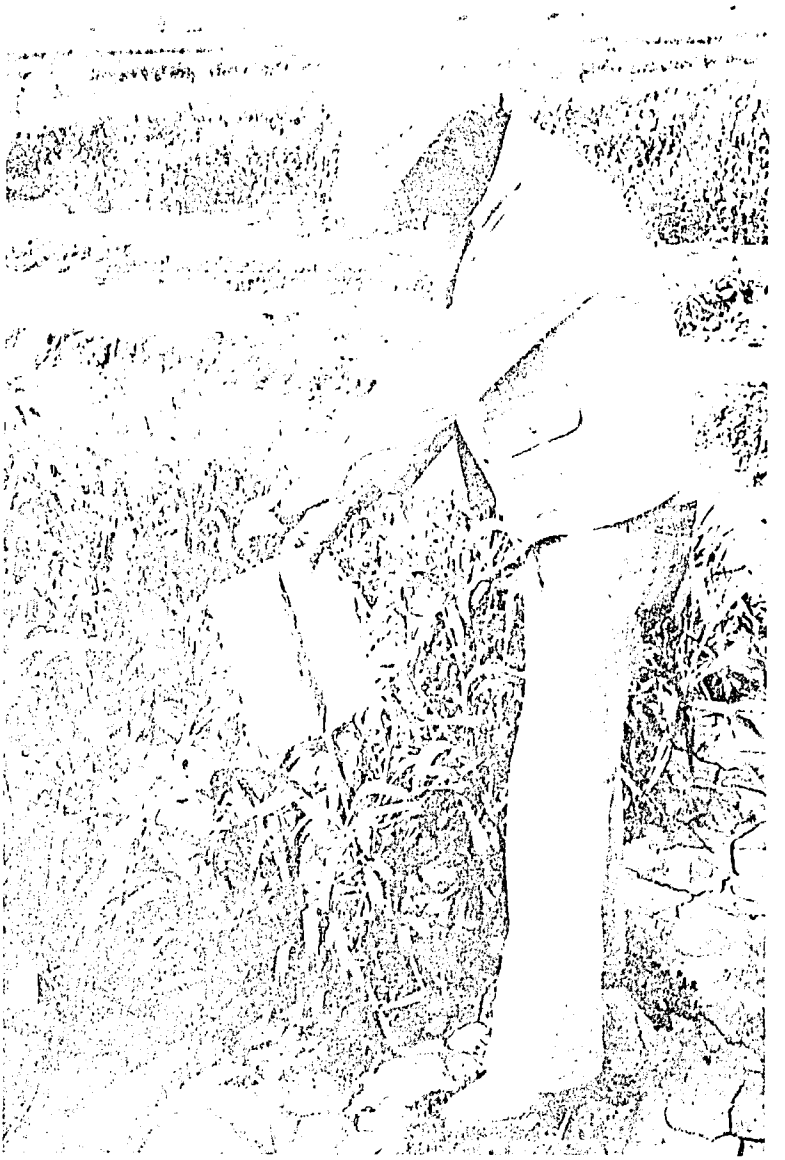
In CIMMYT's conventional breeding programs, experimental lines are evaluated simultaneously for many desirable traits. Lines that carry a particular character useful to the breeder, but contain a large number of undersirable traits, are usually rejected. To capitalize on potentially valuable germplasm, CIMMYT has a special germplasm development unit that attempts to transfer useful genes into lines with good agronomic characters.

During 1981, a number of special germplasm development activities were under way. In some cases, these special research activities were either brought to a conclusion, transferred to the conventional breeding programs, or reduced in priority. 1981 activities included the following:

1. Work to increase the protein content in high-yielding wheat materials. Only limited progress has been achieved in combining high protein content and high yield potential. Reduced activity with 2 to 3 high protein lines will continue.

2. Work to improve the agronomic characteristics of Brazilian wheats with aluminum toxicity tolerance has been very successful. These breeding materials have been transferred to the bread wheat program which will continue the improvement of aluminum-tolerant wheat materials.

3. Work to improve resistance of wheat to Hessian fly has been discontinued due to the unsuitability of Mexican



Work to improve maximum yield potential in wheat is being approached through studies on yield components. These efforts focus on the development of lines with larger heads, good grain quality, reasonable tillering ability, semidwarf stature, good straw strength, and better disease resistance.

biological conditions to carry out such research. Work to improve resistance to sawfly through the development of solid stem bread wheat, durum wheat, and triticale materials has been quite successful and will continue. Solid stem materials already developed have been transferred to the respective conventional breeding programs.

4. Work to improve rye materials for the triticale program continues. Additional dwarfism is needed in CIMMYT's rye material, as is further improvement in self-fertility, crossability, grain type, and earliness.

5. Improvement in the grain of triticale continues. Durum and bread wheat materials with outstanding grain type are being used to improve the grain plumpness of CIMMYT's high-yielding triticale materials.

6. Work on developing very dwarf wheat varieties (double and triple dwarfs) has been concluded and these dwarf materials have been placed in the germplasm bank for use as sources of dwarfism for conventional breeding programs.

New Directions

Several new activities will be initiated in 1982. These include the development of separate source populations (gene pools) for resistance to *Helminthosporium sativum, H. tritici repentis,* and *Fusarium* spp. for bread wheat, durum wheat, and triticale. The feasibility and practicality of developing these populations is dependent on the availability of a suitable male gametocide or chemical hybridizing agent which will allow for field-level cross-pollination.

Work on crossing triticales and wheat (both ways) will be reoriented. Emphasis in this project will be to introduce rye genes into bread wheat. The introduction of genes from rye has shown that it can improve the yield dependability of wheat (e.g., Veerys). The triticale program will continue to introduce wheat genes to enhance triticale seed characteristics and improve pre-harvest dormancy (e.g., preclude pre-harvest sprouting).

GERMPLASM BANK

Until 1981, the wheat program operated only a minimum short-term cold storage seed maintenance facility for its four 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 properly described, classified, and maintained. This is particularly true for triticale, in which CIMMYT has one of the world's largest breeding programs. The wheat program also needed additional storage space to maintain working collections and for small-scale seed supply increases for other collaborating countries.

With financial assistance from the Government of Japan, CIMMYT built a new wheat germplasm bank facility which was put into operation in late 1981. To properly manage the bank and to classify the large number of accessions, an experienced breeder/germplasm bank curator joined the wheat program staff in 1981. The first cycle of classification (12,000 accessions) was carried out at CIANO, Sonora, during 1981-82. Eventually, a computer program will be developed to assist in the management of this germplasm bank information base.

AGRONOMY RESEARCH

The agronomy research staff engages in three main activities: training, agronomic studies that are not highly site-specific, and agronomic recommendations for CIMMYT's breeding nurseries.

Agronomy training

In training, the staff worked closely with 21 production agronomists from national programs who attended the 1981 CIMMYT in-service production agronomy training courses. These courses emphasize field research and the strengthening of diagnostic skills to solve production problems. In-service trainees help to design and manage a series of agronomic experiments planted on farmers' fields and on experiment stations.

Participation in the agronomy program at base is also being used to train the agronomists who will staff CIMMYT's regional wheat programs. To gain a good understanding of CIMMYT's small grains improvement programs and other research activities, one to two years involvement at base of all CIMMYT wheat agronomists is sought before deployment to outreach posts. Growing support of national and regional short courses in production agronomy is also being provided by the Mexican-based agronomy program staff. In 1981, support was given in a number of field workshops conducted by collaborating national programs.

Research in Mexico

CIMMYT's agronomy research in Mexico is conducted in two distinct regions. In the winter season, from November to May, experiments are conducted around Ciudad Obregon, Sonora, in the northwest of Mexico, in the irrigated, desert-type environment of the Yaqui Valley. This is an ideal environment for studies on yield, drought, and weed control of *Avena fatua* (wild oats) and *Phalaris minor*—two important weed problems in this region.

In the summer season, between May and October, studies are conducted in the upper plateau area around Mexico City. Two of CIMMYT's experiment stations—Toluca, the main CIMMYT summer wheat station, and El Batan, our headquarters—are located in this region. In this rainfed highland environment, agronomic studies focus primarily on weed control (mainly broadleaf weeds) and fertilizer levels.

At all three stations, weed control studies are made to evaluate different chemical and cultural controls for use in breeders' nurseries. To test the most promising control methods for varietal sensitivity before using them in farmers' fields, a systematic series of weed control experiments is carried out, ranging from the initial screening of different chemicals to more critical testing of different rates and times of application on phytotoxicity and weed control.

Although a range of experiments is conducted in both cycles, only two—a long-term integrated weed control study and a variety x nitrogen utilization efficiency trial—will be reported here.

A trial was started in 1979 at CIANO to determine the long-term (4 year) effects of various cultural and chemical

control practices on *Avena fatua* and *Phalaris minor* weed populations. The treatments included methods of incorporation of wheat stubble, the presence or absence of a summer soybean crop, irrigation before or after sowing, wheat seeding density, and chemical control of the grass weeds for none, one, two, or three seasons (see Figure 2). This rather large factorial experiment reveals the importance of rotation patterns and cultural practices in weed control.

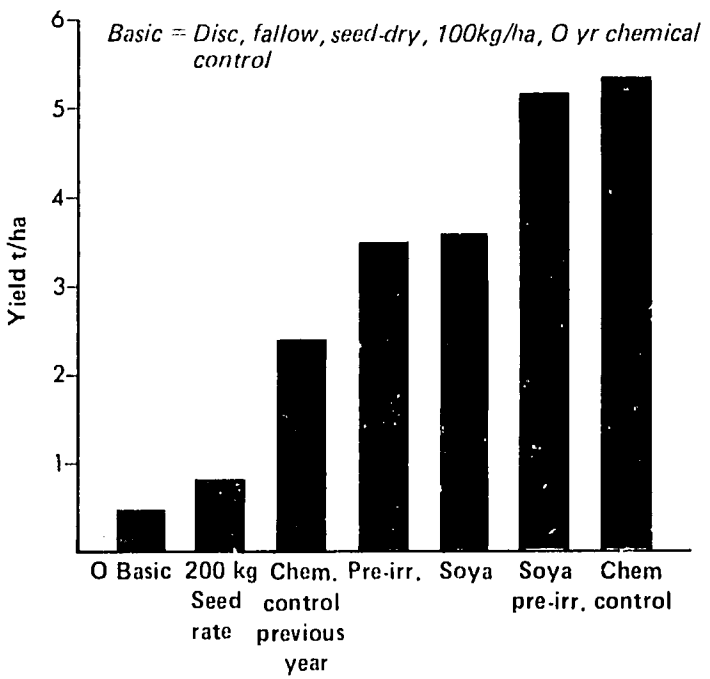


Figure 2. The effect of various treatments and combination of treatments on the yield of wheat in an integrate weed control experiment, CIANO, 1981

As the data show, effective weed control is accomplished through a wheat soybean rotation (other crop rotations may have similar beneficial effects) and a pre-irrigation followed by a discing to incorporate germinated weeds before seeding wheat into moist soil (e.g., "Soya-Pre-irr."). This method controls weed populations almost as well as when a herbicide is used (e.g., "chem. control"). The weed

control offered through pre-irrigation is so marked that many Mexican farmers in the Yaqui Valley have already adopted this practice. Besides the direct benefit of this type of research for making production recommendations to farmers, the experiment also illustrates (for training purposes) the importance of looking at the wheat crop within a total farming system.

In another study, fertilizer response curves under fully irrigated conditions were determined for different wheat varieties released in Mexico between 1950 and 1981 (see Figure 3). The various nitrogen response curves illustrate the input efficiency of the newer semidwarf varieties to make better use of available nitrogen and sunlight for grain pro-

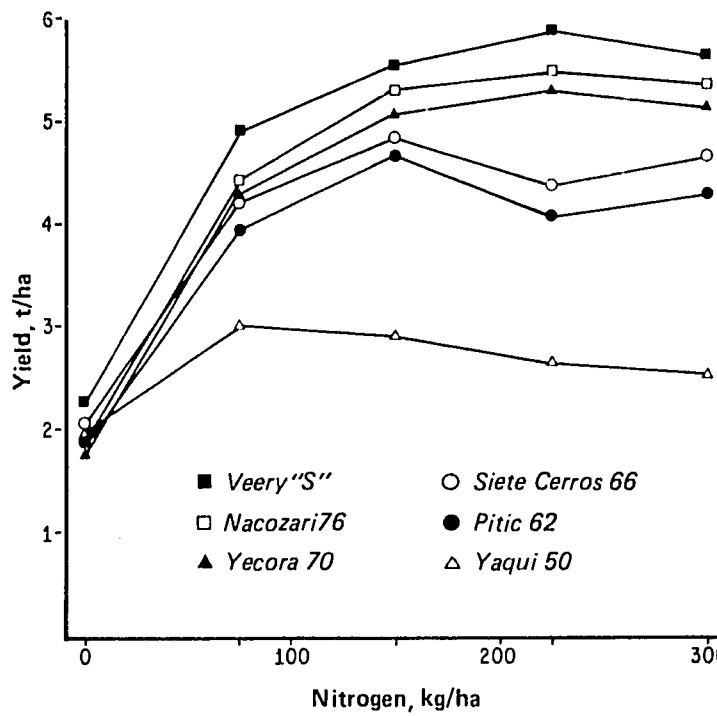


Figure 3. Nitrogen response curves of various wheat varieties released over the last 30 years

duction. They also show the yield superiority of the newer semidwarf varieties compared to the older tall varieties, such as Yaqui 50, even at lower rates of nitrogen fertilizer application.

WHEAT TRAINING

In-service training continues to be a major component in CIMMYT's Mexico-based wheat training activities. Five courses were offered during 1981.

Course	Number of trainees
Wheat Breeding	11
Wheat Pathology	6
Rainfed Wheat Agronomy	15
Irrigated Wheat Agronomy	6
Experiment Station Management	7
Total	45

The demand for CIMMYT-trained wheat production specialists continued to grow during 1981. Due to persistant funding shortfalls, the production courses were restructured during 1981 to maximize the effectiveness of staff time and other available resources. Wheat production courses will now be run concurrently from May through November and will be headquartered at El Batan. Other ways of augmenting our Mexico-based training, such as holding regional and national short-courses and drawing on regional staff and former in-service trainees, are also being attempted and evaluated for cost-effectiveness.

Visiting scientists

The CIMMYT improvement cycle at CIANO attracts scientists from around the world. In 1981, 71 visiting and associate scientists from 26 countries came to CIMMYT, with 60 visiting CIANO during the crossing and selection season

(March and April). Eleven other visiting scientists spent time at the El Batan and Toluca stations during the summer breeding cycle. CIMMYT financed the trips of 35 visiting scientists, mostly from the developing world. In addition to the opportunity to exchange ideas and information with the wheat program staff, visiting scientists are also free to select materials from CIMMYT's wheat, triticale, and barley germplasm and take it back to their home country institutions.

Graduate student training and postdoctoral fellows

During 1981-82, with outside financial sponsorship, CIMMYT is cooperating in the training of eight master's degree students (Algeria and Mexico) and one Ph.D. student (Algeria). In addition, six postdoctoral fellows (Fed. Rep. of Germany, France, Mexico, the Philippines, and the USA) are serving on the wheat program staff.

Training is a critically important activity at CIMMYT. The development of scientists with the ability to identify, analyze, and solve production problems is at the core of all CIMMYT training efforts.

Origin of wheat in-service trainees, 1966-81

	1966-1981	1981
Latin America	166	7
Argentina	14	0
Bolivia	16	1
Brazil	18	0
Chile	12	1
Colombia	5	0
Dominican Republic	1	0
Ecuador	18	0
Guatemala	8	0
Guyana	1	0
Honduras	1	0
Mexico	44	0
Panama	1	0
Paraguay	6	0
Peru	20	4
Uruguay	1	0
North Africa and Mideast	204	6
Algeria	54	2
Cyprus	2	1
Egypt	14	0
Iran	8	0
Iraq	5	0
Jordan	7	1
Lebanon	4	0
Libya	4	0
Morocco	20	0
Saudi Arabia	2	0
Sudan	3	0
Syria	7	0
Tunisia	26	0
Turkey	42	2
Yemen	3	0

	1966-1981	1981
Africa, south of the Sahara	72	13
Cameroon	3	2
Chad	1	0
Ethiopia	14	2
Kenya	8	1
Lesotho	1	0
Madagascar	2	1
Malagasy	1	0
Malawi	2	0
Mali	3	1
Mozambique	1	1
Nigeria	15	0
Rwanda	2	0
Senegal	2	1
Somalia	1	0
Tanzania	6	1
Transkei	1	1
Uganda	1	1
Zaire	2	0
Zambia	7	1
Asia	152	17
Afghanistan	13	0
Bangladesh	37	7
Burma	1	0
India	18	0
Korea	11	1
Nepal	18	3
Pakistan	50	4
Philippines	3	1
Thailand	1	1
Other Countries	22	2
France	1	0
Hungary	2	0
Poland	3	0
Portugal	3	1
Rumania	2	0
Spain	3	0
USA	4	0
USSR	4	1
Total Training Fellows	609	45
Total Countries	66	26

WHEAT COOPERATIVE PROJECTS OUTSIDE MEXICO

Most of CIMMYT's wheat staff posted outside Mexico were assigned to regional programs. Only one staff member was working in a national program assignment (Pakistan), and his work focused mainly on production agronomy research. In 1981, the wheat program had staff assigned to seven regional programs.

Regional wheat programs in 1981

Wheat region and operations base	Number of cooperating countries	Start of CIMMYT arrangement	CIMMYT staff assigned	Current donor
Disease Surveillance (Turkey)	22	1973	1*	Netherlands
Eastern and Southern Africa (Kenya)	17	1976	1*	Core Unrestricted
Andean Countries (Ecuador)	5	1976	1	Core Unrestricted
Southern Cone (Chile)	5	1978	2	Japan/ CIMMYT
North & West Africa & Iberian Peninsula (Portugal)	19	1980	1	Core Unrestricted
ICARDA (Syria)	11	1980	1	Core Unrestricted
South and Southeast Asia (Thailand)	12	1980	1	Core Unrestricted

* A Dutch associate scientist is also assigned to these regions

Disease surveillance regional program

The problems of wheat diseases in an area stretching from Morocco to East Africa to the Indian subcontinent continue to be the major activity for the CIMMYT staff assigned to this program funded by the Government of the Netherlands. In addition to normal regional program activities related to consultation and training assistance, these CIMMYT regional staff are working on two unique projects—a disease surveillance-early warning system for the region and a series

of in-service pathology workshops focused on practical field and laboratory methods for inoculation, screening, and identification of disease-resistant lines.

The regional disease surveillance team prepared and distributed its Regional Disease Trap Nursery (RDTN) in 1981. The RDTN consists primarily of commercial varieties, susceptible check varieties, promising advanced lines with new sources of rust resistance, and differentials for the three rusts. The RDTN serves as a surveillance mechanism for changes in pathogen races throughout the region. It is sent annually to 150 locations in about 50 countries. The Dutch government has provided a grant and technical assistance to develop a computerized statistical package to process the data reported by collaborators growing these regional nurseries. In 1981, a Dutch pathologist continued his assignment in Turkey as an associate staff member in the program.

Eastern and Southern African regional program

This region includes 17 African countries from Ethiopia in the north to Lesotho in the south. The small grains currently grown in this region are mostly in the highland areas above 1,700 meters altitude, an agroclimatic zone characterized by the presence of serious disease problems. The CIMMYT staff member assigned to this region helps to operate an off-season nursery program at Kenya's National Plant Breeding Station at Njoro, 2,140 meters above sea level. (A pathologist assigned by the Dutch government to Kenya also continued to collaborate with the regional program as a staff associate.)

This off season nursery is used by many African and Asian countries, mainly for disease screening and to be able to complete two breeding cycles in a single year. The area around Njoro is characterized by virulent biotypes of stem rust and stripe rust, and is an excellent area to screen lines for good disease resistance.

In several countries in the region foliar diseases, such as *Septoria* and *Helminthosporium,* cause serious damage. In Ethiopia and Tanzania, very effective screening has been possible for *Septoria tritici.* In Zambia, wheat grown under rainfed subtropical conditions suffers from *Helminthosporium sativum.* Recently, selected lines have shown good levels of tolerance in Zambia.

Triticale has continued to show excellent yields in several areas under experimental conditions. Several countries are now working out the pricing of triticale relative to wheat. Commercial production in Kenya has been estimated at 4,000 ha. Tests with flour mixtures of wheat and triticale have produced very acceptable loaves of bread.

In most countries in the region wheats with tolerance to acidic soil conditions are much desired. Old varieties such as Romany have shown wide adaptation, but yield levels and disease resistance are no longer adequate. Recently, wheats introduced from Brazil and Mexico have shown good performance in acid soils, and combine good yields with rust resistance. These new lines must now be evaluated widely within the region.

Stem rust resistance is receiving considerable attention from breeders in Ethiopia. Crossing work has been focused on improving yield levels, plant types, and rust resistance. The improved types can be planted much earlier in the season, and will utilize the rainfall more efficiently.

Two regional nurseries were prepared and distributed in 1981 by the staff assigned to this program—the African Cooperative Wheat Yield Trial (ACWYT) and the Screening Nursery for the African Cooperative Wheat Yield Trial (SNACWYT), each of which are sent to about 20 countries each year.

Andean regional program

CIMMYT has had a wheat scientist assigned to this region since 1976 to work with the national program scientists in the five Andean countries. The staff member is based in Quito, Ecuador, under an agreement with Ecuador's national agricultural research institute (INIAP). In mid 1982 a wheat agronomist will join this regional program.

Virulent forms of stripe rust and barley yellow dwarf virus make this area of considerable value in global screening efforts to develop lines with greater resistance to these diseases. Three regional nurseries were prepared and distributed in 1981 by the staff assigned to this program—the Latin American Wheat Disease and Observation Nursery (VEOLA), the Latin American Rust Nursery (ELAR), and the Regional Andean Wheat Trial (ERTA).

The VEOLA is a regional disease and insect screening nursery which consists of advanced lines of bread wheat, durum wheat, triticale, and barley. In addition to supplying regional disease information, the VEOLA facilitates the exchange of disease-resistant materials identified in other CIMMYT regional nurseries. The nursery is a cooperative effort of CIMMYT and INIAP.

The objective of the ELAR, which is similar to the RDTN, is to survey virulence patterns of wheat pathogens, thus serving as an early warning system for new biotypes of rusts. The ELAR contains rust differentials and commercial varieties and lines originating from breeding programs throughout the Western Hemisphere and is distributed to about 30 sites in Latin America.

Southern Cone regional program

This regional program began in late 1978 and covers areas of five Southern Cone countries of South America. Two CIMMYT scientists—a breeder and an agronomist—are assigned to the area, with their operations base at Chile's national agricultural research institute (INIA) and with cooperative ties to IICA, the Inter-American Institute of Agricultural Cooperation.

In crop improvement, disease resistance research is focused on the three rusts, various types of septoria, barley yellow dwarf virus, fusarium, helminthosporium, and root rots.

During 1980, at a meeting of wheat breeders of the region organized by IICA-BID Cono Sur Project, CIMMYT was asked to coordinate a screening nursery of advanced lines (LACOS) to be distributed within the region and at key locations in the Andean countries and Mexico. The nursery is being prepared through the joint effort of CIMMYT and INIA, Chile. It will provide various breeding programs of the region a chance to observe unreleased promising wheat material from other programs in terms of their adaptation, agronomic, and disease characters. Subsequently, some of these lines may be used as progenitors in national wheat improvement programs, or be released as commercial varieties Several Southern Cone rust virulence nurseries were merged with the ELAR to coordinate the effort between the two regions.

Special emphasis is also being placed on soil-fertilizer problems related to wheat, barley, and triticale production. In particular, the problems associated with aluminum toxicity and phosphorus fixation tendencies are receiving major research attention. The regional agronomist is working with national scientists to establish trials in farmers' fields for the purpose of identifying yield constraints and increasing production.

In Chile, agronomic collaboration is focused on production trials conducted mainly on farmers' fields to identify the limiting technical factors in wheat production. Work on management techniques to reduce the incidence of root diseases is receiving attention. Scientists are also looking at the effect on foot rot problems when various soil amendments are applied.

In Argentina, work focuses on soil fertility management strategies brought on by new double-cropping patterns that have emerged with the release of short-season varieties which allow greater cropping intensification. Trials are being carried out in the Pergamino area to investigate nitrogen and phosphorus deficiencies. The trials show that phosphorus deficiency is becoming a widespread problem in the *Pampa Humeda*. Nitrogen response trials are demonstrating a significant response to nitrogen in the Marcos Juarez area, where most farmers still do not apply nitrogen to wheat.

North and West Africa and Iberian regional program

This program began operation in 1980 and covers North and West African countries west of Egypt and Sudan, as well as Spain and Portugal. The operations base is in Portugal at the Elvas station of the Ministry of Agriculture. At present, one wheat breeder is assigned to the program. Close collaboration exists with ICARDA, and joint staffing may occur in future years.

Special breeding priorities include disease resistance research on septoria and the three rusts. In addition, breeding work is being carried out to develop wheat and barley cultivars with greater drought and heat tolerance. During 1981, a two-week regional disease research methodology workshop was held for regional scientists through funding from the Dutch government. In addition to acquiring practical research

CIMMYT's regional wheat training activities continue to expand. In 1981, a two-week disease research methodology workshop was held in Portugal for young national wheat scientists from North and West Africa, Spain, and Portugal.

skills, each country that sent participants received a set of pathology research equipment.

ICARDA

Since 1980, CIMMYT has assigned a wheat breeder at Aleppo, Syria, at ICARDA's request. This scientist is working mainly to develop bread wheat germplasm with greater cold and drought tolerance and resistance to rusts, for use by national program scientists in the Middle East and in parts of North Africa.

South and Southeast Asia regional program

In mid-1980, CIMMYT placed a wheat pathologist in Thailand to help establish and serve the South and Southeast Asia region. Much of his work involved cooperating with national programs in Nepal, Bangladesh, Pakistan, India, and

Southeast Asia countries. Considerable emphasis is being given to developing wheats for warmer, non-traditional, wheat-growing areas. A number of countries in this region, and on other continents as well, are interested in growing wheat during their winter seasons, when temperatures and humidity are at their lowest levels. Serious disease constraints under these conditions are *H. sativum* and *H. tritici repentis.* Work on resistance to these diseases will be emphasized by the regional staff, as will efforts to develop early-maturing lines appropriate to the relatively short growing season typical of prevailing production conditions.

economics program

INTRODUCTION TO THE ECONOMICS PROGRAM

The economics program at CIMMYT is now ten years old. While the activities of staff economists have evolved over this period, the focus on farm-level production issues relevant to the development and diffusion of improved maize and wheat technologies has remained unchanged.

Shortly after the initiation of the program, a number of studies were carried out on farmer adoption of improved maize and wheat technologies in cooperation with scientists in several national programs. The results, published in 1974-75, showed the overriding importance of natural and economic forces in determining patterns of adoption. These also gave evidence that recommended technologies were, at times, not well suited to the circumstances of representative farmers. Finally, they made evident the advantage of bringing biological scientists and economists together early in research aimed at formulating improved technological alternatives. This, in turn, led to an awareness of the need to develop effective procedures for facilitating such collaborative research.

In the on-farm research collaboration envisioned by CIMMYT, the biological scientist brings his perception of the natural factors and relationships which affect farmer decision-making. The economist adds his awareness of the alternative uses of the farmer's resources and of the economic considerations that impinge on his ability to modify current management practices. The insights of economists into farmer decision-making, in terms of trade-offs and the importance they place on time when assessing potential investments and pay-offs, have proved to be especially important considerations in research to develop near- and intermediate-term recommendations appropriate to farmer circumstances.

Recognizing that it is researchers in national programs who are responsible for forging improved technologies and formulating recommendations, CIMMYT economists have built their collaborative ties with national program scientists, usually in cooperation with CIMMYT maize and wheat pro-

gram staff. Out of this collaboration has come a set of cost-effective guidelines for orienting on-farm research so as to generate appropriate recommendations.

As the economics program moves into the 1980s, our focus will continue to be at the production level. We envision expanding collaboration in on-farm research activities, emphasizing the important role economists can play in assessing farmer circumstances and drawing out the implications of these circumstances for orienting production research programs. Demonstrations of these procedures and training in their use are increasingly requested by national research directors. As those demands increase, our on-farm research collaboration will continue to expand.

New research initiatives are also planned. Too often, decisions at the national level have not facilitated the development and diffusion of improved technologies—often because the links between policy and the biological processes in agriculture are little understood. We believe that greater awareness of these links can result in more effective national production programs and increased farm income. We aim to enhance this critical sensitivity by developing useful procedures for generating, analyzing, and presenting micro-level information—derived primarily from on-farm research data—to national decision makers. As with the procedures described earlier, this development will also require close collaboration with colleagues in national programs.

In the pages which follow, highlights of the economics program's activities in 1981 are described. We believe that these activities reflect an important added dimension in increasing the productivity of the resources now devoted to maize and wheat research.

D.L. Winkelmann

CIMMYT ECONOMICS PROGRAM

The CIMMYT economics staff is engaged in four principal activities: the development of research procedures for analyzing the production circumstances of maize and wheat producers; training of national collaborators in certain on-farm research techniques; collaborative research (through the regional program network) with national maize and wheat production research organizations; and the compilation and analysis of data related to developing country and global trends in maize and wheat production, utilization, prices, and trade.

PROCEDURES

Over the last decade, CIMMYT's economics staff has worked with scientists in many national programs to develop a set of procedures which offer cost-effective ways to assess the production circumstances of farmers. This information is then used to orient research aimed at developing improved technologies. These procedures are now being used by many national programs and are proving to be an effective way to bridge the gap which often has separated researchers from farmers and from extension workers. A manual based on these procedures was published in late 1980 and has received considerable attention during 1981. We are now developing a companion piece in the form of a workbook to complement the manual.

Two major components characterize on-farm research. The first phase is devoted to ascertaining—through secondary data and informal and formal surveys—the production circumstances of representative farmers in target research areas. These circumstances are then screened to identify potential opportunities for further on-farm research. This phase is best carried out by a research team which includes agronomists and economists. The total sequence, including surveys and screening, is relatively uncomplicated and quick (2 to 4 months in any region). It differs from other survey sequences

in its emphasis on production problems related to a given crop or crop mixture.

The second phase of this research model involves the design of a program of on-farm experimentation. These experiments focus on research opportunities identified through the survey procedures. The primary objective of on-farm research is to develop production recommendations appropriate to the circumstances of representative farmers.

This set of procedures offers a conceptual framework for production-oriented research. It provides a systematic mechanism for assessing farmers' circumstances, guidelines for using this information to plan on-farm experiments, criteria to help judge the utility (practicality) of the various technological alternatives, and a mechanism to feed pertinent information on production problems back to scientists engaged in experiment station research. Finally, it offers a practical way to integrate extension staff into the research process, thereby improving and facilitating the technology transfer process.

Work is now under way to develop cost-effective research procedures to aggregate, analyze, and present information generated by on-farm surveys and trials for use at national policy-making levels. Several audiences are considered in the development of these procedures. One is the policy maker, who often lacks a clear view of the opportunities for increased productivity through biological research. Another audience is the researcher himself, who may not be aware of the connections between public policy and research.

TRAINING

During 1981, the economics staff participated in the instruction of maize and wheat in-service trainees in Mexico, offered its own training programs in on-farm survey methodologies, and participated in national in-service training courses.

In-service training

Maize and wheat in-service production trainees spend roughly one-sixth of their stay in Mexico focusing on the

economic aspects of crop production. Along with the maize and wheat training officers, CIMMYT economists seek to foster an increased sensitivity in the trainees to the factors affecting farmer decision-making about new technologies.

Economists work with the trainees in the field as they talk to farmers, analyze their circumstances, and understand the reasoning behind their practices. They assist trainees to analyze the implications of the survey information for planning on-farm trials. Finally, trainees are made aware of the economic forces that influence agricultural decisions, both at the farm and national levels.

Economics training program

The training program in economics has now been offered once or twice a year since 1979. In 1981, two courses were held. These courses are principally for economists engaged in on-farm maize and wheat research activities. They focus on procedures for assessing farmer circumstances and on how to use that information to help plan on-farm experiments. The program involves field work with either maize or wheat in-service production trainees. The major activity is the design, execution, and analysis of a farmer survey to provide information for decision-making on research priorities. The curriculum also includes attention to analytical tools, to the influence of national policies on production, and to world wheat and maize economics.

The demand for this training in on-farm research procedures is strong and growing, both in national programs and in development assistance agencies. Consequently, we are developing a new version of the course which can be given as part of a national in-service training activity in on-farm research. In this course, CIMMYT headquarters-based and regional maize and economics staff assist national trainers in procedures for conducting an on-farm research program. A pilot course was launched in Venezuela in late 1981 in conjunction with the regional maize staff. The course involves a series of "calls" beginning with a review of secondary data and other information to tentatively identify regions for research and to order priorities. Subsequent "calls" deal with other elements of on-farm research and are carried through to the analysis of data from on-farm trials. The in-country setting for this type of training appears to

offer a number of cost-effective advantages over other forms of training. In particular, the real life setting for conducting an on-farm research program is particularly useful to the national program. Not only is training achieved but, as well, progress is made on the formulation of recommendations for a particular production area.

Management seminars

Management seminars for decision-makers, sponsored in part through a UNDP special project grant, were held in Bangladesh, Colombia, and the Dominican Republic during 1981. Cases addressed themes related to the orientation of agricultural research, the production and distribution of improved seed, the distribution of fertilizers, and crop marketing issues. These seminars now have shown their value as a method to improve communications between policy makers and agricultural researchers.

After study and discussion, it was decided that this activity should be transferred to ISNAR. During 1982, an expanded seminar activity will be initiated by ISNAR utilizing a broader gamut of case studies, with emphasis on the organization and implementation of agricultural research. CIMMYT continues to cooperate in the development of case materials and is pleased with its role in offering a new and effective training tool to the CGIAR system.

DATA COLLECTION AND ANALYSIS

More data collection and analysis activities on maize and wheat production, utilization, trade, and prices are under way in the economics program. Two new publications titled "World Wheat Facts and Trends" and "World Maize Facts and Trends" were issued in 1981. These publications serve two purposes. One is to assemble on a regular basis pertinent data related to maize and wheat production, consumption, and trade, and to present this information in a readily digestible form for the busy policy-maker, researcher, or administrator. The second objective is to report on new developments in maize and wheat production and utilization in the developing world.

A number of other studies, particularly related to trends in consumption patterns for maize and wheat, are also in process. Finally, the economics staff is continuing its survey work to help characterize the different wheat production environments within the developing world.

REGIONAL PROGRAMS

CIMMYT's regional economists worked in four regions in 1981. These staff members cooperated in collaborative research aimed at the development of technologies useful to farmers. This collaboration involved bringing local economists together with biological scientists in on-farm research activities; consulting on the organization of micro-level research; providing some financial support for such research where necessary, and cooperating in drawing out the implications of this research for production-oriented programs of experimentation. The aim is to convince research administrators of the utility of this approach to technology generation and to encourage its development within national programs.

Eastern African regional program

The regional economist, supported by funds from UNDP since 1976, worked regularly with national research programs in Kenya, Malawi, Zambia, and Zimbabwe during 1981. Throughout 1981, the regional economist had the assistance of a predoctoral fellow who is working with a Kenyan training program for farm economists engaged with crop scientists in on-farm research.

Interest in on-farm research is high in Malawi and several sessions were undertaken with researchers working in national institutions. In Zambia, on-farm research has been institutionalized within the national research system and is now under way in four production areas. In Zimbabwe, a full demonstration of the CIMMYT survey research procedures was carried out during 1981. A program of experiments based on the survey work have now been implemented in the survey area. Zimbabwe will build its capacity to do on-farm research within its Agronomy Institute, a division of Research and Specialist Services. In Kenya, survey research expanded into new production areas.

Two regional workshops, each lasting two weeks, were held in Kenya during 1981. The first, a workshop on planning, managing, and interpreting on-farm experiments, was held in April and attended by 42 participants. A CIMMYT maize production agronomist participated in the program. A second workshop, held in October, focused on the CIMMYT survey procedures for planning adaptive on-farm experiments, and included 32 participants from 13 African countries.

Considerable consultation was also given to international donor agencies interested in supporting more on-farm research within national research programs. USAID has decided to commit funds to expand the Eastern African Economics Program through the addition of two staff members. Several national on-farm research programs in the region are now being financed through USAID funds, and CIMMYT staff will collaborate with these programs.

South and Southeast Asian regional program

The regional economist, based in Thailand since 1979, is assisting maize and wheat researchers (economists and agronomists) in five Asian countries (Bangladesh, Indonesia, Nepal, Philippines, and Thailand). Of these, collaborative research was strongest with three countries—Indonesia, Nepal, and Thailand.

Work in Indonesia centered on maize production in East Java and has included a series of surveys and on-farm experiments. The overriding importance of short-season maize varieties was a key outcome of the research to date.

In Nepal, a survey of maize growers in the Chitwan Valley, near Rampur, looked at farmer practices, problems, and yield levels. On-farm trials to evaluate varieties and management practices were continued, and results were submitted to simple economic analysis. A critical question was farmer reluctance to invest in new inputs other than improved seed.

In Thailand, maize-related activities included collaboration in general large-scale surveys of the traditional type (cost-of-production, input use, output), small-scale intensive surveys of farmers on whose fields on-farm trials were being conducted, and a series of on-farm trials on varieties and management practices. Considerable attention was given to the analysis of fertilizer trials. A modest research effort was

initiated in support of wheat program work investigating the possibilities of producing wheat in Thailand.

Other activities were initiated with the Philippines in strengthening wheat-related on-farm research. In Bangladesh, some collaboration was carried out in relation to on-farm wheat experiments of varieties and fertilizer. A paper was prepared analyzing the economics of fertilizer use.

Andean regional program

Since late 1977, an economist has been posted to the Andean region for collaborative research work in Colombia, Ecuador, Peru, and Bolivia. This work has concentrated on floury maize, a dominant crop in the highlands; on tropical maize in the coastal regions; and on wheat and barley, secondary crops in highland farming systems. Within the region, two countries—Ecuador and Peru— have made strong national commitments to on-farm research.

Ecuador has expanded its on-farm research program to eight major production regions within the country. Development assistance agency funding has helped to staff this expanded program. Considerable impact from on-farm research in the program is becoming evident. A new short-season maize variety has been introduced which allows farmers to intensify cropping cycles. The Ecuadorian researchers, complemented by IARCs, continue to improve other crops used in association or rotation with maize. In particular, bean breeders are seeking to identify and/or develop less aggressive bean varieties to be grown in association with the new short-season maize variety recently introduced in some highland areas. Research to identify new technological opportunities from the introduction of that innovation is now under way.

In Peru, on-farm research is focused on highland maize production and on wheat production in new irrigated coastal areas. The irrigated wheat effort is supported by special project funding from CIDA.

During 1981, the regional economist participated with the regional maize staff in several field workshops on survey procedures and on farm experiments for both wheat and maize. Courses were offered in Ecuador and Venezuela, using a "call system" in which participants are convened at critical stages in the research cycle. One course focused on wheat production in highland Ecuador and the other, a more

Considerable impact is becoming evident from collaborative on-farm research activities in Ecuador. A new short-season maize variety which allows farmers to intensify their cropping cycles has been identified and is being introduced into highland areas.

ambitious effort, on maize production in Venezuela. Headquarters and regional maize, wheat, and economics staff participated in these training programs.

Central American and Caribbean regional program

The regional economist, assigned to this region since 1978 and supported by Swiss funding, concentrated his early work in Panama and El Salvador. In 1981, work in Honduras and Haiti was expanded in collaboration with the regional maize staff. In country workshops in on-farm research were held in Haiti, Honduras, and Panama.

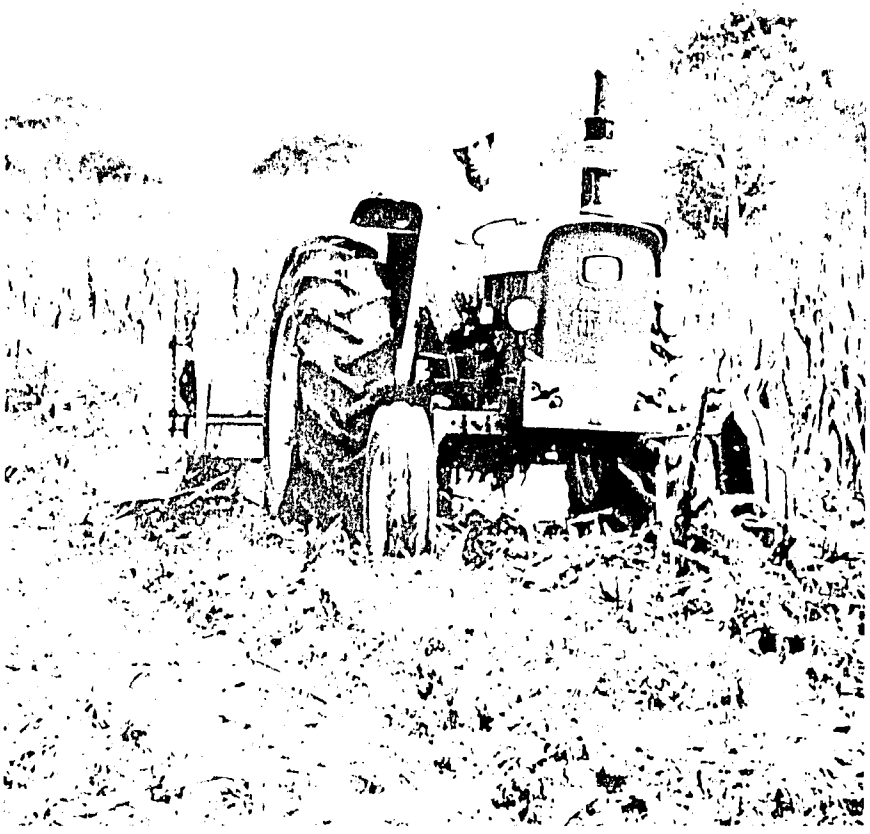
In Panama, the national agricultural research institute (IDIAP) has now extended its on farm research activities to new areas of the country and to other crops. Farm surveys have been completed to guide subsequent on-farm trials. Although the CIMMYT economist has reduced his direct

involvement in demonstrations of the survey procedures, his collaboration with Panamanian scientists in the analysis of on-farm data is continuing. During 1981, a short course in economics was conducted for the national on-farm research staff.

In 1980, cooperation in on farm research was initiated with Honduran researchers, in collaboration with the regional maize staff. The work began with the assessment of farmer circumstances in several maize-producing areas. This information has been used to plan a series of on-farm trials aimed at indentifying and/or developing appropriate production recommendations. A short course in economics was also given to national staff engaged in on-farm research.

In Haiti, with the arrival in 1981 of a postdoctoral fellow funded by the Rockefeller Foundation, CIMMYT's collaboration in farm-level research has increased. As with other national activities in the region, the regional maize staff is fully involved in the work. Surveys have been completed in several maize-producing areas and a series of on-farm trials are now under way. An informal training program was also organized by the regional maize and economics staff during 1981. It covers informal survey techniques, the design of trials, and the economic evaluation of results.

supporting services



EXPERIMENT STATIONS

CIMMYT conducted research at seven stations in Mexico during 1981. Three belong to Mexico's national agricultural research institute (INIA), and four belong to CIMMYT.

Station	Altitude (m)	Latitude (°N)	Hectares Used by CIMMYT	Crop Season
CIANO–INIA	39	27	176(wheat*)	Nov-May
Los Mochis–INIA**	40	26	2(wheat)	Dec-May
Rio Bravo–INIA**	30	26	1(wheat*)	Dec-May
El Batan–CIMMYT Headquarters	2,240	19	26(maize)	Apr-Dec
			26(wheat*)	May-Nov
			4(sorghum***)	Apr-Oct
Toluca–CIMMYT	2,640	19	43(wheat*)	May-Nov
			5(wheat*)	Dec-May
			15(maize)	Apr-Dec
Poza Rica–CIMMYT	60	20	41(maize	Dec-May First cycle
			4 sorghum***)	Jun-Nov Second cycle
			1(wheat)	Nov-May
Tlaltizapan–CIMMYT	940	18	31(maize)	Dec-May First cycle
			1(sorghum***)	Jun-Dec Second cycle

* Includes barley and triticale
** CIMMYT nurseries planted for observation on diseases
*** Sorghum as a service to ICRISAT

In addition to supporting the research requirements of the CIMMYT crop improvement programs, the experiment station staff also conducted two training courses in experiment station management and continued with its program of overseas consultation to national programs on experiment station development and management.

LABORATORY SERVICES

CIMMYT maintains laboratories to evaluate the nutritional and/or industrial quality of the breeding materials

generated by the maize, wheat, triticale, and barley breeding programs. The major work is for industrial quality in wheat (milling and baking laboratory) and nutritional quality in maize (protein quality laboratory). Laboratory staff also provides service to the wheat program by screening materials for resistance to aluminum toxicity. In addition, training and consultation is given to scientists from collaborating national programs.

DATA PROCESSING SERVICES

This unit provides computing services to the maize, wheat and economics programs, and to general administration. These include: support for the international maize and wheat testing programs; production of wheat program fieldbooks, plot tags, and packet labels; maize germplasm bank inventory maintenance and control; economic survey analyses; and analyses of a variety of other experiments conducted by CIMMYT scientists. During 1981, work was also completed on a computerized mailing list to support the communications section.

During 1981, site preparation began to install a new scientific computer to serve the CIMMYT programs, using grant funds provided by the governments of the Federal Republic of Germany and Mexico. This new system will be installed in early 1982 and will substantially increase CIMMYT's computing capacity.

INFORMATION SERVICES

Thirty-eight new publication titles were issued in 1981, and distributed to scientists and other interested parties included on CIMMYT mailing list of 4,000 names. With our encouragement, a number of national collaborators translated CIMMYT publications into local languages, printing and issuing them under national imprimatures. In addition, the Commonwealth Agricultural Bureau (CAB) of the United Kingdom issued on behalf of CIMMYT Volume 7 of the Maize Quality Protein Abstracts and Volume 7 of the Triticale Abstracts.

PUBLICATIONS RELEASED BY CIMMYT IN 1981

Title	Language	Pages	Press Run
ADMINISTRATION			
CIMMYT Today 13, CIMMYT Economics	English	16	4,500
CIMMYT Hoy No. 13 Economia en el CIMMYT	Spanish	16	3,000
CIMMYT Today 14, Maize Research and Production in Guatemala	English	16	4,500
CIMMYT Hoy No. 14, Investigacion y Produccion de Maiz en Guatemala	Spanish	16	3,500
CIMMYT Review 1981	English	108	4,750
Informe del CIMMYT 1981	Spanish	116	2,500
CIMMYT 1982 Mid Term Budget Request	English	32	500
"World Wheat, Facts and Trends 1981 Report"	English	20	3,000
"World Maize, Facts and Trends 1981 Report"	English	32	4,000
MAIZE			
1978 79 Maize Improvement Report	English	136	1,750
1980 International Maize Testing Program, Preliminary Report	English/Spanish	190	750
1980 International Maize Testing Program, Final Report	English/Spanish	358	750
Maize Diseases Booklet	Turkish	92	350
Bulletin Improving Adaptation and Yield Dependability in Maize in the Developing World	English	18	2,000
WHEAT			
1979 Wheat Improvement Report	English	190	1,500
4th Regional Workshop Proceedings, Vol. 2	English/French	207	1,250
Bulletin Nepal Ridge	English	8	1,000
Bulletin India Matlines	English	12	2,250
Nursery Reports			
Results of the Twelfth International Bread Wheat Screening Nursery (IBWSN) 1978 79 (IB60)	E S F *	64	1,250
Results of the International Barley Observation Nursery Second 1974 75, Third 1975 76, Fourth 1976 77 (IBON) (IB61)	E S F *	36	1,250
Results of the First International Barley Yield Trial (IBYT) 1978 79 (IB62)	E S F *	48	1,250
Results of the Tenth International Triticale Yield Nursery (ITYN) 1978 79 (IB63)	E S F *	88	1,250
Results of the Tenth International Durum Yield Nursery (IDYN) 1978 79 (IB64)	E S F *	64	1,250
Results of the Tenth International Triticale Screening Nursery (ITSN) 1978 79 (IB65)	E S F *	32	1,250
Results of the Second International Barley Yield Trial (IBYT) 1979 80 (IB66)	E S F *	36	1,250
Results of the First Elite Selection Wheat Yield Trial (ESWYT) 1979 80 (IB67)	E S F *	24	1,250
Results of the Sixteenth International Spring Wheat Yield Nursery (ISWYN) 1979 80 (IB68)	E S F *	92	1,000
Results of the Thirteenth International Bread Wheat Screening Nursery (IBWSN) 1979 80 (IB69)	E S F *	112	750
Results of the Eleventh International Triticale Yield Nursery (ITYN) 1979 80 (IB70)	E S F *	84	750
Results of the Eleventh International Durum Yield Nursery (IDYN) 1979 80 (IB71)	E S F *	64	750
ECONOMICS			
"Planeacion de Tecnologias Apropiadas para los Agricultores Conceptos y Procedimientos"	Spanish	72	3,000
Working Papers Series			
"An Agro Economic Evaluation of Maize Productions in Three Valleys of the Peruvian Andes"	English	26	500
"Farmers' Practices, Production Problems and Research Opportunities in Barley Production in the Calpulalpan/Apan Valley, Mexico	English	60	500
"Demonstrations of an Interdisciplinary Approach to Planning Adaptive Agricultural Research Programs in the Serenje District, Zambia"	English	38	500
"A Users Guide to FASAP A Fortran Program for the Analysis of Farm Survey Data"	English	52	500
"Manual para los Usuarios de FASAP Un Programa en Fortran para el Analisis de Datos de Encuesta de Agricultores"	Spanish	52	500
"Accelerated Wheat Production in Semi Arid Developing Regions Economic and Policy Issues"	English	36	500
"Methodological Issues Facing Social Scientists in On Farm Farming Systems Research"	English	34	550

* English Spanish French

financial statement

Price Waterhouse

México, D. F., February 26, 1982

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

In our opinion, the accompanying statement of condition and the related statements of activity and of changes in financial position, expressed in United States dollars, present fairly the financial position of Centro Internacional de Mejoramiento de Maíz y Trigo, A. C. (CIMMYT) at December 31, 1981 and 1980 and the results of its operations and the changes in its financial position for the years then ended, in conformity with generally accepted accounting principles consistently applied. Our examinations of these statements were made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Our examinations were made primarily for the purpose of forming our opinion on the financial statements taken as a whole. We also examined the additional information presented on Exhibits 1 to 8, expressed in United States dollars, by similar auditing procedures. In our opinion, this additional information is stated fairly in all material respects in relation to the financial statements taken as a whole. Although not necessary for a fair presentation of financial position, results of operations and changes in financial position, this information is presented as additional data.

PRICE WATERHOUSE

C.P. Oscar Córdova

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO, A.C.

STATEMENT OF CONDITION

Currency: Thousands of U.S. Dlls.

A S S E T S

	As of December 31 1981	1980
Current Assets		
Cash on Hand and in Banks	1,582	880
Short-Term Investments (Note 2)	2,050	253
	3,632	1,133
Accounts Receivable		
Donors (Note 2)	690	152
Others (Note 7)	528	1,020
	1,218	1,172
Inventories	231	235
Total Current Assets	5,081	2,540
Fixed Assets (Note 2)		
Vehicles	2,251	1,770
Furniture, Fixtures and Equipment	2,635	1,878
Buildings	5,797	5,525
Land	464	464
Other Fixed Assets	372	372
Total Fixed Assets	11,519	10,009
Other Assets		
Guarantee Deposits	1	1
Deferred Charges	-	3
Total Other Assets	1	4
TOTAL ASSETS	16,601	12,553

LIABILITIES, CAPITAL GRANTS, UNEXPENDED FUNDS AND RESERVES

	As of December 31 1981	1980
Current Liabilities		
Payments in Advance - Donors (Note 2)	830	-
Vouchers Payable	2,663	794
Seniority Premiums (Note 2)	64	62
Accrued Taxes	186	364
Accrued Miscellaneous Expenses	16	266
Accounts Payable - Donors	42	42
Total Current Liabilities	3,801	1,528
Capital Grants, Unexpended Funds and Reserves		
Capital		
Fully Expended on Fixed Assets	11,519	10,009
Operating Funds (Note 4)	1,540	1,215
	13,059	11,224
Unexpended Funds (Note 5)		
Core Unrestricted	15	11
Core Restricted	19	19
Extra Core and Cooperative Projects	(48)	(48)
Auxiliary Services	(25)	(21)
	(39)	(39)
Translation Effect (Note 3)	(312)	(252)
Trustee Reserve	92	92
Total Capital Grants, Unexpended Funds and Reserves	12,800	11,025
TOTAL LIABILITIES AND CAPITAL	16,601	12,553

The attached notes numbered 1 to 7 form an integral part of these Financial Statements.

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO, A.C.

COMPARATIVE STATEMENT OF ACTIVITY

Currency: Thousands of U.S. Dlls.

	Year ended December 31, 1981	1980
REVENUE (Note 6)		
Grants	20,337	17,559
Administrative Fees	533	634
Sale of Crops	26	43
Interest on Investments in Marketable Securities	214	(2)
Auxiliary Services	719	479
Other Income	3	6
TOTAL REVENUE	21,832	18,719
EXPENSES (Note 6)		
Research Programs	12,771	11,409
Conferences and Training	2,560	2,536
Information Services	691	615
General Administration	1,821	1,377
Plant Operations	2,032	1,758
Capital Acquisitions	326	395
Auxiliary Services	723	484
Indirect Costs	533	652
Seniority Premiums	50	25
Operating Funds	325	-
TOTAL EXPENSES	21,832	19,251
EXCESS (DEFICIT) OF REVENUE OVER EXPENSES	-	(532)
Translation Effect for the Year	(60)	23
EXCESS (DEFICIT) OF REVENUE OVER EXPENSES	(60)	(509)
Unexpended Funds, Opening Balance	(39)	493
Accumulated Translation Effect, Opening Balance	(252)	(275)
Closing Balance Unexpended Funds and Accumulated Translation Effect as per Statement of Condition	(351)	(291)

The attached notes numbered 1 to 7 form an integral part of these Financial Statements.

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO, A.C.

STATEMENT OF CHANGES IN FINANCIAL POSITION

Currency: Thousands of U.S. Dlls.

	Year ended December 31, 1981	1980
FINANCIAL RESOURCES WERE PROVIDED BY:		
Revenue	21,832	18,719
Capitalization of Fixed Assets Purchased in the year		
Core Unrestricted Grants	1,260	1,209
Core Restricted Grants	250	250
Extra Core Grants	-	111
Increase in Operating Funds	325	-
Translation Effect of the year - Net	(60)	22
Decrease in Other Assets	3	69
	23,610	20,380
FINANCIAL RESOURCES WERE USED FOR:		
Expenses	21,832	19,251
Less- Expenses not requiring working capital in the year:		
Contingency Reserve	-	168
Working Capital used for operations	21,832	19,419
Purchases of Fixed Assets		
Core Unrestricted Grants	1,260	1,209
Core Restricted Grants	250	250
Extra Core Grants	-	111
	23,342	20,989
Increase (Decrease) in Working Capital	268	(609)
ANALYSIS OF CHANGES IN WORKING CAPITAL ACCOUNTS		
Cash on Hand and in Banks	702	(120)
Short-Term Investments	1,797	(97)
Accounts Receivable:		
Donors	538	(214)
Others	(491)	(241)
Inventories	(4)	11
Payments in Advance - Donors	(830)	-
Bank Loans	-	441
Vouchers Payable	(1,870)	(268)
Seniority Premiums	(2)	34
Accrued Taxes	178	(166)
Accrued Miscellaneous Expenses	250	(15)
Accounts Payable - Donors	-	26
Increase (Decrease) in Working Capital	268	(609)
Working Capital at beginning of year	1,012	1,621
Working Capital at end of year	1,280	1,012

The Attached notes numbered 1 to 7 form an integral part of these Financial Statements.

CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO, A.C.

NOTES TO THE FINANCIAL STATEMENTS

DECEMBER 31, 1981 AND 1980

Currency: Thousands, except for exchange rates

NOTE 1 - STATEMENT OF PURPOSE:

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

NOTE 2 - SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES:

CIMMYT follows accounting policies recommended by the Secretariat of the Consultative Group on International Agricultural Research (CGIAR), an international association sponsored by the World Bank, the Food and Agriculture Organization of the United Nations, and the United Nations Development Programme. These policies are in accordance with generally accepted accounting practices for not-for-profit organizations and are summarized below.

a. CIMMYT uses the accrual method of accounting for transactions and its books of account are kept in U.S. dollars. Transactions in other currencies (mainly Mexican pesos) are recorded at the rates of exchange prevailing on the dates they are entered into and settled. Assets and liabilities denominated in such currencies are translated into U.S. dollars at the rates prevailing on closing dates. The resulting translation differences are applied to income.

b. During periods of cash surplus CIMMYT makes short-term investments in marketable securities. These are denominated in dollars and are transacted in the U.S. or Eurodollar money market. Interest

is credited to income when the security matures or is sold. The security is recorded at cost, which approximates market, and any gain or loss from its sale is recorded at that time. Investments in pesos are held in a short-term interest-bearing account in a Mexican bank. These are non-negotiable fixed rate instruments. Interest is credited to income as accrued.

c. Accounts Receivable - Donors: Core unrestricted pledges (also referred to as grants) are given annually and are charged to accounts receivable when the amount of the donation becomes known. The receivable is cancelled when the funds are received. Any uncollected portion of the pledge applicable to the current year remains charged to accounts receivable and forms part of the institution's income in that year. If the pledge is later judged to be uncollectible it is written off against income of the year in which it is cancelled.

Core restricted and extra core pledges, which are often for more than one year, are treated somewhat differently. In these cases the amount recognized as a receivable is equal to the expenses incurred under the grant. The uncollected portion of the pledge is not recognized as a receivable and consequently does not contribute to income. Only when expenses are incurred under the grant is an account receivable created and income recorded. This treatment matches revenues and expenses in accordance with the level of activities carried out under the grant. This accounting policy permits CIMMYT to distinguish between income and amounts pledged in core restricted and extra core grants. This is necessary since these grants often cover more than one year's activities or contain carry-forward provisions in cases of underexpenditure. Recognizing the total pledge in a given year as income could result in an overstatement of

income. Core unrestricted grants do not require this treatment since they are given annually and the amount pledged represents income for that year.

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

e. Fixed assets - Amounts are stated at acquisition cost. Up to 1971 all purchases of property and equipment were recorded as expenses. In 1971 the Consultative Group requested that the International Agricultural Research Centers change to the "write off, then capitalize" method of recording purchases of property and equipment. Accordingly, all property and equipment purchased under capital grants as from January 1, 1972, was recorded as an asset and credited to capital grants.

Prior to 1980 replacements of capital items were recorded as expenditures of the related programs, and did not enter in any way to form part of CIMMYT's capital grants, shown on the statement of condition. In 1980, this policy was revised to conform with the accounting policies of the Consultative Group on International Agricultural Research. Under this set of guidelines, the incremental value of a capital replacement item, i.e., the amount by which the historical cost of the replacement item is greater (less) than the historical cost of the item being replaced, is credited (debited) to capital grants fully expended on fixed assets. In this way, the statement of condition reflects the historical cost of the fixed assets actually in use. Implementation of this policy resulted in a restatement of fixed assets and capital grants in 1980 amounting to U.S. $1,101 over what would have been recorded under the previous policy.

In 1980 CIMMYT capitalized two items that were funded by res-

tricted grants. The first of these, a new dormitory for visiting scientists donated by the Government of the Federal Republic of Germany, was capitalized at U.S. $116, the total cost of the building. The second of these, a storage facility for wheat germplasm donated by the Government of Japan, was capitalized at $250. The second phase of this project was completed in 1981 and capitalized at $250.

Also in 1981 the first phase of a program to modernize CIMMYT's computer facilities was completed, resulting in additions to capital of $697. Phase two of this project will be completed in 1982.

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

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

g. Seniority premiums, to which employees are entitled upon termination of employment after fifteen years of service, are recognized as expenses as such premiums accrue. The estimate of the accrued benefit determined on the basis of an actuarial study as of the year end amounted to $216 in 1981 and $292 in 1980 and CIMMYT had recorded a liability of $63 in 1981 and $62 in 1980. The charge to income for the year amounted to $50 in 1981 and $25 in 1980, including amortization of past service cost over 10 years.

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

NOTE 3 - MEXICAN PESO TRANSACTIONS:

At December 31, 1981 CIMMYT had Mexican peso assets and liabilities amounting to Ps31,927 (Ps14,088 in 1980) and Ps12,664 (Ps22,076 in 1980), which were included in the statement of condition at their U.S. dollar equivalents resulting from applying the year-end rate of Ps26.06 per dollar.

The fluctuation of the peso gave rise to translation income (loss) aggregating $(60) in 1981 and $23 in 1980. As of December 31, 1981 and 1980, the cumulative translation effect amounted to ($312) and ($252) respectively.

On February 17, 1982, Banco de México, S.A. (the central bank) announced that it was withdrawing from the international exchange market and would let the parity of the peso vis-a-vis other currencies be determined through the free interplay of supply and demand. On February 26, the date of issuance of the financial statements, the exchange rates were Ps46.00 (buy) and Ps47.00 (sell) to the U.S. dollar.

NOTE 4 - OPERATING FUNDS:

The CGIAR permits CIMMYT (and all other international agricultural research centers funded through it) to maintain, as part of the center's capital accounts, operating funds equal to thirty days of its core operating budget. This is not a requirement, however, and in 1980 CIMMYT elected not to increase its operating funds. These funds were used instead as part of the expenditures on on-going programs. In 1981 CIMMYT increased its operating funds by $325, and thus restored them to their permitted level.

NOTE 5 - UNEXPENDED FUNDS:

Since 1978 CIMMYT has been instructed by the Secretariat of the Consultative Group on International Agricultural Research to use

its core unrestricted unexpended funds to finance, in part, the annual core operating budget of succeeding years. For this reason CIMMYT registered a deficit of Revenue over Expenses and a decrease in unexpended funds in 1980. This depleted virtually all unexpended funds such that in 1981 activities were financed from revenue received in the year.

NOTE 6 - REVENUE AND EXPENSES:

a. Revenue. CIMMYT's revenues are grouped into six categories:

i) Grants. These are funds received from donors and are used to support two types of programs at CIMMYT: core and extra core. Core programs must fall within the mandate of the center and be approved by the institution's Board of Trustees. The secretariat of the CGIAR then recommends that the core program be supported by its members. These include governments, government aid agencies, international and regional development banks, and private philanthropic foundations (see Exhibit 4). Core programs are divided into two groups: unrestricted and restricted. Unrestricted grants come with only one requirement: that the funds be used to support core activities. Restricted grants also support core activities but they must be used for an activity mutually agreed upon by CIMMYT and the donor.

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

ii) Administrative fees. These fees are charged on restricted and extra core grants. They permit CIMMYT to offset the cost of administering these grants, which by design only fund specific research activities. See Exhibit 8 for the calculation of these fees.

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

iv) Interest on Investments in Marketable Securities. Surplus cash is invested in short-term interest bearing securities, and any interest earned is recorded as income. Similarly interest expense arising from short-term borrowings to cover cash deficit positions is charged to this account. In 1980 these borrowing costs exceeded interest income.

v) Auxiliary Services. These comprise revenues from the following areas within CIMMYT: Cafeteria, Laundry, Guest House, Dormitories and Staff Residences. As a whole, they are intended to be self-supporting.

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

b. Expenses. The breakdown of CIMMYT's expenses as shown in its Statement of Activity is largely self-explanatory. Included under Research Programs, the largest single expenditure, are the expenses of the Maize, Wheat, Economics, Experiment Stations, Laboratories and Data Processing units. In 1981 and 1980 their expenses were as follows:

	1981	1980
Maize	4,123	3,770
Wheat	4,952	4,252
Economics	835	1,002
Experiment Stations	2,159	1,744
Laboratories	328	341
Data Processing	369	265
Others	5	35
TOTAL	12,771	11,409

NOTE 7 - ACCOUNTS RECEIVABLE - OTHERS:

In 1981 and 1980 Accounts Receivable - Others were comprised as follows:

	1981	1980
Rotating Funds	-	117
Personal Charges to Employees	(15)	100
Official Expenses Advances	210	304
Employee Credit Union	66	102
Government of Mexico	81	63
Miscellaneous Debtors	186	334
TOTAL	528	1,020

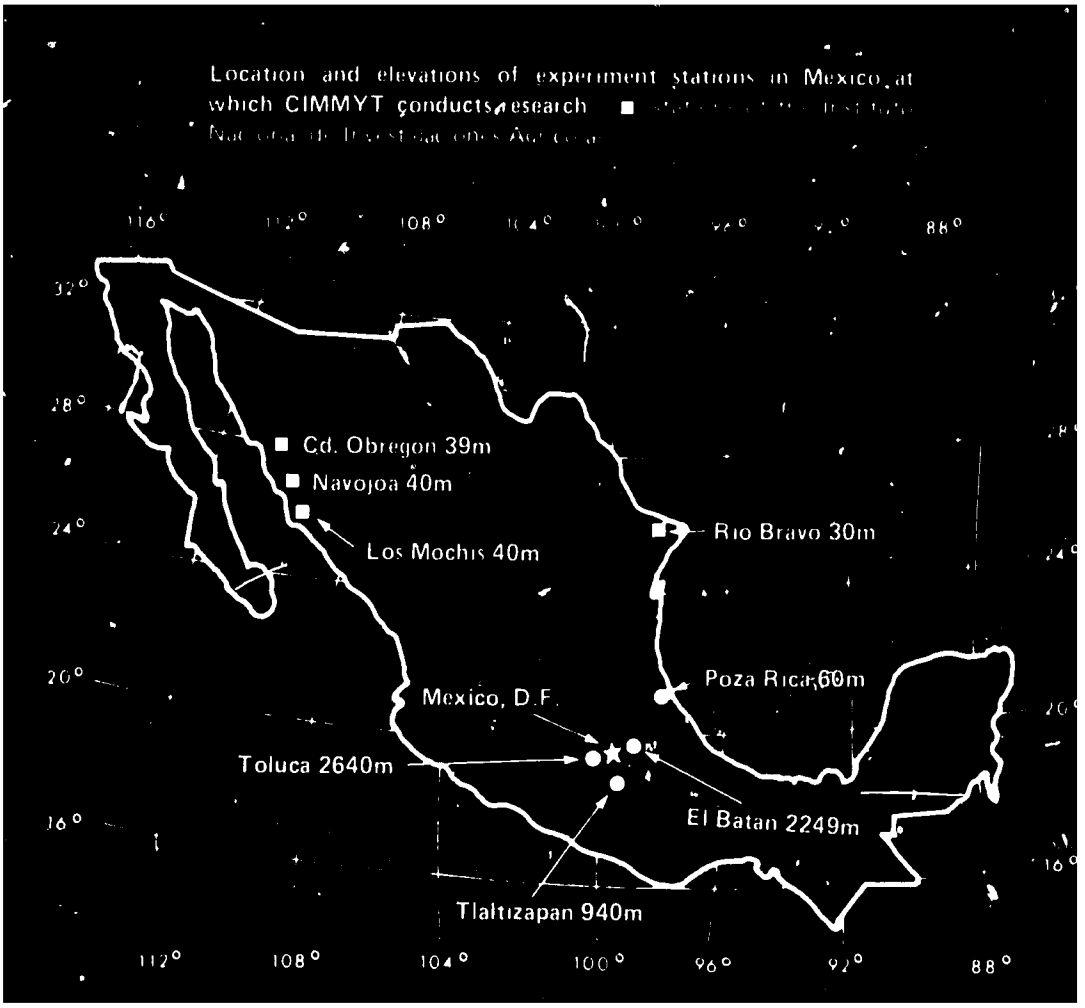
During 1981 rotating funds and official expenses advances were reclassified under one account.

ISSN 0304-5463

Correct Citation: Centro Internacional de Mejoramiento de Maíz y Trigo. CIMMYT Review 1982. El Batan, Mexico. 1982.

Spanish edition: CIMMYT Review 1982 is published in English and Spanish. A copy of the Spanish edition is available on request.

CIMMYT. The International Maize and Wheat Improvement Center (CIMMYT) receives support from government agencies of Australia, Canada, Denmark, France, Japan, Mexico, Norway, Spain, Switzerland, The Federal Republic of Germany, The Netherlands, The Philippines, The United Kingdom, USA and Zaire; and from The Ford Foundation, Inter-American Development Bank, Patronato of Sonora, The Rockefeller Foundation, United Nations Development Programme, and the World Bank. Responsibility for this publication rests solely with CIMMYT.

Se dió término a la impresión de este libro el 10 de agosto de 1982 en los talleres de Abeja. Tiro 4,500 ejemplares.

ISSN 0304-5163