CIMMYT REVIEW
1980

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CENTRO INTERNACIONAL DE MEJORAMIENTO DE MAIZ Y TRIGO 1980
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DIRECTOR GENERAL's INTRODUCTION

CIMMYT Review 1980 is intended to provide highlights of CIMMYT program activities during 1979 for the informed laymen. It is complemented by two technical annual reports (maize and wheat), more than a dozen international testing annual reports, and various other information bulletins published by CIMMYT each year.

In addition, a special CIMMYT planning report has been published describing projected research priorities and program activities during the period 1981-86.

During 1979, the wheat program leadership changed for the first time. Norman Borlaug, who guided and inspired the wheat staff since CIMMYT's inception, has now become a consultant to the program. His contributions to the agricultural sciences and to mankind are so widely known and acknowledged that they need no explanation here.

Dr. R. Glenn Anderson has been in charge of directing the wheat program staff since July 1979. To assist in providing program direction, a scientist from within the program who understood—and had contributed to CIMMYT's program development was chosen as the Associate Director. Dr. Arthur Klatt assumed these responsibilities in 1979. He is young, energetic and has done outstanding work in his CIMMYT assignments beginning in 1968, first at base in Mexico, later in Turkey with the national wheat program, and most recently in the Andean regional program. His array of experiences will serve CIMMYT well.

1979 marked the end of Phase III of the CIMMYT/UNDP maize protein quality improvement project. Remarkable progress has been achieved in this research effort and UNDP has agreed to support the program for another five years

The process of developing regional programs continued during 1979. The mideast regional maize program was established with a CIMMYT scientist based in Turkey. Regional wheat programs in the Mediterranean and Mideast and East Africa were strengthened through the arrival of two Dutch associates, on loan from the Government of the Netherlands. Two postdoctoral fellows also joined regional economics programs in the Andean region and East Africa. During the 1980s, a growing responsibility of these regional staff will be to help strengthen the production research activities of collaborating institutes throughout the developing world.

R. D. Havener

maize improvement

INTRODUCTION TO MAIZE PROGRAM

World 1980 crop production estimates made by the United States Department of Agriculture place maize in first place in terms of total world crop production. About 50 per cent of this maize is grown in the USA, and on a global basis, 65 to 70 per cent goes for livestock and poultry feed. This total production level, however, does reflect the production potential of maize as a global food source in the years ahead.

To date, vast differences exist between the yields of maize planted on the well-watered plains of North America and Europe and yields obtained in most developing countries. Tropical maize is unlike the grain-efficient types found in the temperate areas. While an efficient producer of dry matter, the partitioning to grain and stover in tropical maize is inefficient from the point of view of grain production.

Research at CIMMYT, however, shows that the partitioning of tropical maize can be altered more toward the 1:1 grain-to-stover ratio of the more productive temperate types. For the future, improvements in tropical maize materials for greater grain efficiency, disease and insect resistance and better agronomic characteristics hold tremendous promise for substantial increases in cereal yields in the developing world.

In the pages which follow, the highlights of CIMMYT's maize program activities in 1979 are presented. In brief, we can report continued progress toward making maize a more productive and dependable crop for developing country growing conditions.

E.W. Sprague

MAIZE SUMMARY

Back-up unit

Systematic evaluations of some of the 13,000 collections in the maize germ plasm bank continued in 1979. Superior materials were added to the appropriate gene pools. Fifty-five samples of seed from the bank were also sent to collaborating maize scientists who requested specific types of germ plasm.

Gene pools formed to serve different ecological zones, grain type preferences and maturity characteristics continued to be improved for yield, maturity and disease and insect resistance.

Preliminary evaluation trials of materials not already in the international testing program were conducted in 1979 at a range of worldwide testing sites to identify potential areas of adaptation. Pools to serve highland areas were reorganized to better meet the germ plasm needs in this area. Work on new temperate x tropical pools continued.

Advanced unit

The progeny from half of the advanced unit populations (in 1979 that meant 13 populations out of 26) were distributed for international testing. The best entries from this testing program will be used to form future experimental varieties. Trials were conducted in Mexico in 1978 and 1979 to determine the progress achieved in improving CIMMYT's advanced materials. Progress is evident in developing greater disease and insect resistance in these high-yielding materials. The results of these trials confirm the effectiveness of the CIMMYT breeding system put into effect in 1974.

Eighty-four countries requested experimental trials in 1979. A sampling of data returning from these trials shows the breadth of superior materials that are emmanating from the collaborative international maize testing program. An increasing number of countries are making requests to CIMMYT for additional seed with the intention of local seed multiplication and demonstrations on farmers' fields.

Quality protein improvement

Data from 1978-79 on the best quality protein materials show that the yield performance of these types are at a par with their normal counterparts in the CIMMYT improvement program, and yet have added protein quality as a plus.

Collaborative research on disease resistance

Collaborative research on three major diseases—downy mildew, streak virus and corn stunt—continues. In 1979, the superior families with resistance to downy mildew and corn stunt were internationally tested for the first time. The results indicate that good progress has been made toward increasing the genetic resistance of maize to these diseases.

Special research activities in Mexico

Progress continues to be made on improving the grain efficiency of tropical maize. A special project on techniques to develop greater drought tolerance is showing promise. Research also continues on developing earlier maturity characters in high-yielding tropical maize types and in broadening the adaptation of maize germ plasm.

Wide crosses

Work continues on wide crosses between maize and sorghum, and maize and *Tripsacum*: the aim is to transfer to maize potentially useful genes from alien genera to make maize more environmentally stable. A few intergeneric hybrids were produced in 1979.

Maize training

Seventy-two trainees from 26 countries received in-service training in Mexico in 1979. Many other categories of personnel were also involved in CIMMYT-assisted training opportunities including 10 master's degree candidates and 5 predoctoral and postdoctoral fellows.

Maize cooperative projects outside Mexico

Seven CIMMYT staff were assigned to national maize programs in 1979. An additional seven scientists were posted to regional programs in Asia, Africa and Latin America. Considerable emphasis in all these programs is being given to production agronomy research.

BACK–UP UNIT

CIMMYT's maize program is designed for a multidisciplinary focus on a wide range of problems that have restricted maize production in the developing world. The population improvement strategy followed by CIMMYT begins in the "Back-Up Unit," which is charged with the first stages of improvement for different types of maize germ plasm. The Back-Up Unit evaluates maize materials from around the world (new introductions), maintains a working germ plasm bank, and creates and improves gene pools constituted on the basis of climatic adaptation, grain type, maturity characters, and grain colors and textures. Each year, superior introductions and bank accessions are systematically evaluated and added to the corresponding gene pools. Superior germ plasm in these gene pools is identified and transferred to the corresponding advanced populations which have reached a sufficient level of improvement for distribution to national collaborators.

GERM PLASM BANK

At the end of 1979, the maize germ plasm bank held over 13,000 collections of maize, which represent the vast amount of genetic variation found within the species in the Americas and other parts of the world. The germ plasm bank unit conserves, regenerates, tests and catalogs the different collections of maize (and related species) for use by CIMMYT and other interested organizations.

Regeneration of collections

Seed is frequently removed from the bank for use by CIMMYT and other collaborators. When the amount of seed in storage of any collection falls below 500 g it must be regenerated. In 1979, 224 accessions from tropical and temperate areas were planted to regenerate the bank's seed supply.

Shipments to collaborators

CIMMYT offers on request free samples of seed from the bank to all research organizations. In 1979, 55 seed requests were filled from more than 20 countries. Over 700 different samples were sent.

INTRODUCTION NURSERIES

During 1979, about 1,000 new introductions from tropical lowland, subtropical-temperate and tropical highland areas were evaluated in Mexico. These new introductions were evaluated for agronomic attributes including maturity, height, yield potential and reaction to certain diseases and insects. The superior materials were added to the appropriate gene pools.

Improvement of pools

CIMMYT has developed 27 different gene pools for three broad ecological zones with sub-categories for grain types and maturity characters (see table 1). At present there are gene pools for tropical lowland zones, for subtropical-temperate areas, and for tropical highland regions.

The evaluation of maize materials sent to CIMMYT by national collaborators is part of a continuing strategy to broaden the genetic base of maize grown in the tropics and subtropics. After testing in Mexico, the best entries from these introduction nurseries are added each year to the corresponding back-up unit gene pools.

Table 1. Agro-climatic characteristics considered in classifying maize gene pools.

Adaptation and Maturity range	Altitude (m)	Latitude	Temperature*	Days to silking
Tropical lowland				
early	0-1600	0-30°N-S	25-28°C	Up to 50
medium	0-1600	0-30°N-S	25-28°C	50-59
late	0-1600	0-30°N-S	25-28°C	60 and more
Tropical highland				
early	1600 +	0-30°N-S	15-17°C	Up to 70
medium	1600 +	0-30°N-S	15-17°C	70-94
late	1600 +	0-30°N-S	15-17°C	95-120
Temperate-subtropical				
early	0-1600	30-40°N-S	20-22°C	Up to 60
medium	0-1600	30-40°N-S	20-22°C	60-75

* Mean of main growing season.

All gene pools were improved in 1979 using the half-sib selection method (half-brother or half-sister) as modified by CIMMYT. These pools are grown twice a year in Mexico at several locations. The seed of the best ears from the best plants of superior families in each pool are used to form the next improvement cycle of the pool.

Improving insect and disease resistance in pools

Each of CIMMYT's 27 maize gene pools is being improved for resistance to the principal disease and insect problems encountered in the area it is to serve (e.g. borers, fall armyworms, ear rots and stalk rots).

Scientists inoculate different pools with disease-causing organisms or infest them with insect larvae according to the principal disease and insect problems threatening each pool. The seed of superior plants in the families tested each cycle are retained for the following cycle. In 1980 this procedure is being applied to eight tropical lowland pools, three temperate subtropical pools and three highland pools.

All pools which had completed three cycles of inoculations or infestions by the end of 1979 will be tested in 1980 to determine the progress achieved in developing greater disease and/or insect resistance.

Progress in improving pools

In 1979, all tropical and subtropical pools were evaluated to determine the progress made over recent cycles in the traits undergoing improvement.

Considerable progress has been made in increasing yield and reducing height and maturity in all the pools. In those pools which have undergone nine cycles of improvement, the latter cycles yielded 16 per cent more, were nearly 3 days earlier and 20 cm shorter than in the initial cycle.

Preliminary Evaluation Trials (PETs)

Three PETs were conducted during 1979, primarily to evaluate the performance of materials not already part of the international maize testing program. The PETs were separated by the type of materials evaluated (early lowland tropical materials, medium-to-late lowland tropical materials, and subtropical temperate materials). The trials were conducted in 19 countries at 58 sites. The evaluation of these PETs in various national programs helps to identify potential areas of adaptation as well as problems which should receive priority in germ plasm improvement.

Promotion of materials to the Advanced Unit

In CIMMYT's maize improvement system, the superior portions of gene pools are either transferred to corresponding advanced populations or are used to form new populations. In 1979, 760 half-sib families were promoted to the various advanced populations. In addition, 791 half-sib families were used to form three new advanced populations.

Reorganization of highland pools

A major portion of the world's tropical highland maize is grown in the Andean countries of South America. Here, the predominant maize is the floury type with large, soft kernels. These types are usually late in maturity. Earlier, high-yielding types could increase the flexibility in cropping patterns and reduce the yield losses due to frost and ear rots. In the rest of the highland tropical world, the preferred maize types have flint and dent kernels.

To better serve the maize preferences of highland tropical areas, CIMMYT's highland pools were reorganized in 1979. Four new floury gene pools and three hard endosperm

CIMMYT's highland gene pools were reorganized in 1979 to better serve the maize preferences of highland tropical areas. These highland pools are being improved in collaboration with scientists from the Andean region, particularly Ecuador.

gene pools were formed. As the need arises, additional highland gene pools may also be formed.

These highland gene pools are being improved in collaboration with the national maize program of Ecuador, where a CIMMYT scientist is stationed. The pools are grown once a year in Mexico at our El Batan and Toluca stations, where they also are being improved for resistance to ear rots and earworms, two important production problems in Andean maize. Using a shuttle breeding approach alternating between Mexico and Ecuador, two cycles of improvement are being carried out each year in the earlier pools. The growing cycle of the later maturity pools is too long to permit two improvement cycles each year; consequently they are grown only once a year.

New temperate x tropical gene pools

Historically, temperate and tropical germ plasm have not been intermixed. This has resulted in a narrowing of the genetic base of both types.

In 1978, CIMMYT began to assemble three new gene pools in cooperation with maize scientists from the USA and Europe. These new broad-based pools have been formed according to their adaptation to (1) the extreme northern range of the temperate region, (2) the southern temperate range and (3) the intermediate belt of the temperate region. The objective of these pools is to introduce exotic germ plasm into temperate base materials, which in turn will serve as a mechanism to move genes from the temperate region materials into tropical and highland germ plasm.

During 1979, the pools were grown in Mexico. Once they are thoroughly recombined, the pools will be distributed for widespread multilocational testing and selection with the aim of broadening their adaptation.

CIMMYT also is collaborating with scientists at the University of Hohenheim, Germany, in the development of an exotic maize gene pool. This pool is evaluated each year in the summer cycle in various countries of Europe and at several sites in Mexico. Some of the materials in this pool are showing greater earliness and added cold tolerance.

ADVANCED UNIT

The Advanced Unit is comprised of an interdisciplinary team who engage in population improvement and international testing. A variety of different populations, corresponding to the pools mentioned previously, have been assembled on the basis of climatic adaptation (tropical, subtropical, temperate), maturity period (early, intermediate, late), grain color (white, yellow), and kernel type (flint, dent). Variable relative weights are given to the different traits needing improvement according to the geographic areas each population is meant to serve. In one population, greater disease and insect resistance may receive first priority. In another, greater earliness or better husk cover may be given the highest priority. Multilocational testing, followed by recombination of superior materials, was specifically designed

CIMMYT's Advanced Unit is responsible for the refinement and handling of those maize materials which are ready for international testing. These improved materials are shorter in height, more uniform, mature earlier and are agronomically superior in general.

for continuous improvement in the adaptability and yield dependability of these maize populations, as well as for identification of superior germ plasm for use by national collaborators.

Within the total maize improvement process—from raw germ plasm to commercial varieties—the Advanced Unit concentrates on population improvement and three phases of international testing: progeny trials, experimental variety trials and elite experimental variety trials.

These activities are designed to: (1) serve national programs that are characterized by different levels of capacity and (2) to combine into one mechanism a system for continuous improvement of maize germ plasm as well as a delivery system for improved germ plasm to and from national programs.

Each year CIMMYT selects the best progenies from half its advanced maize populations (in 1979 that meant 13 populations out of 26). These trials are sent to six locations worldwide, selected as representative sites for the particular population in question.

For each population, a collaborator receives seed of 250 progenies from a single advanced population, which he grows in comparison with six checks, which should be the best locally available commercial varieties or hybrids. From this trial the collaborator chooses the 10 best progenies on the basis of yield, plant height, maturity, resistance to diseases and insects, and standability.

When CIMMYT receives a collaborator's report listing the 10 best entries at his testing location, the breeders in Mexico create an experimental variety—using remnant seed—intercrossing the 10 progenies in all possible combinations. The seed of these crosses is then bulked to produce an experimental variety identified by the year and site where the progeny trial was conducted (e.g. Suwan 7539). Each experimental variety will be tested the following year at 30 to 40 sites worldwide.

The reported data from all sites growing a particular experimental variety trial are used to identify the best performing varieties across all locations, which then are used to form an elite experimental variety trial for widespread testing the following year.

Evaluating population improvement in Mexico

Thirteen populations which had completed two or three cycles of improvement were tested in 1978 and again in 1979 to get a measure of the breeding progress accomplished. The results of this special trial showed an overall improvement for all populations and a significant yield increase over two or three cycles of improvement for six populations. In four populations, the average maturity also was reduced significantly. A general decrease in plant height was also observed.

The results of these trials confirm the effectiveness of the full-sib (full brother—full sister) breeding system used by the Advanced Unit since 1974.

DISEASE AND INSECT RESISTANCE

CIMMYT's entomologists and pathologists work as a part of the interdisciplinary maize team to develop materials with resistance to diseases and insects. They evaluate and select for resistance in raw germ plasm, in back-up gene pools and in advanced populations in Mexico. They produce disease-causing inoculum and rear insects in the laboratory and apply these destructive agents, using uniform application procedures, to thousands of maize plants each year to select for resistant plants.

For disease resistance, the pools and populations are inoculated with stalk and ear-rotting organisms. At harvest time, each family is scored for disease damage, and progenies with the least damage are retained for future recombinations.

The development of maize materials which suffer less damage because of pests is central to CIMMYT's improvement strategies. Here, staff are preparing to inoculate plants with stalk rotting organisms to identify genetic sources of resistance to this production problem.

For insect resistance, selected pools and populations are infested in Mexico with larvae of fall armyworms, earworms, and several classes of borers. These are the most important maize pests in the western hemisphere and are related to species causing serious problems on other continents. At appropriate intervals after infestation, visual ratings for insect damage are made for each family. Progenies showing the least damage are retained for recombination and future selection cycles.

INTERNATIONAL TESTING

In 1979, CIMMYT shipped 615 sets of maize trials for testing by collaborators in 84 countries. These shipments included 76 progeny trials for testing in 28 countries; 62 quality protein maize population trials for testing in 40 countries; 244 experimental variety trials for testing in 83 countries; and 233 elite experimental variety trials for testing in 79 countries.

By the end of 1979, results from about 32 per cent of these trials had arrived in Mexico. Therefore, the report on international testing which follows will be based upon 1978, since the final reports are available for that year.

International Progeny Testing Trials (IPTTs)

The superior progenies from the populations tested in 1978 were selected to form 37 new experimental varieties. These varieties carry the names of the sites/locations where the IPTTs were originally tested. Forty-five per cent of the site-specific progeny selections for experimental variety development had mean yields superior to any of the six checks included by national collaborators in each IPTT trial.

Experimental Variety Trials (EVTs)

In 1978, seven different EVTs were assembled, and 295 sets were requested by national collaborators. Some of the best-performing experimental varieties in each of these EVTs are compared in table 2 to the best checks at individual sites where the particular trial was grown. One quality protein maize trial, consisting of 23 varieties (EVT 15), also was included.

Table 2. Sampling of data from international maize experimental variety trials, 1978.

	1978 EVT number	Name of top experimental variety (EV)	Yield (kg/ha)	Yield of top EV as % of best check
Latin America				
Bolivia (Santa Cruz)	14B	San Andres 7632(2)	3482	131
Costa Rica (Los Diamantes)	12	Across 7643	5966	126
Dominican Republic (San Cristobal)	13	Poza Rica 7728	4579	138
Mexico (Tlaltizapan)	16	Cali 7642(2)	8254	138
Peru (Piura)	13	Tlaltizapan 7736	4962	140
Africa and Mideast				
Egypt (El Gemmeiza)	12	Across 7644	5645	127
Ethiopia (Alemaya)	17	Batan 7660	5333	157
Lesotho (Thaba Tseka)	16	Obregon 7748	3420	127
Saudi Arabia (Hofuf)	13	Poza Rica 7728	4844	148
Senegal	15	Obregon 7738	4352	127
Zaire (Gandajika)	12	Across 7643	7127	144
Asia				
Burma (Yezin)	14A	Santa Rosa 7624(3)	3194	169
Nepal (Rampur)	14B	Ilonga 7530	4030	192
Pakistan (Pirsabak)	15	Tocumen 7639	4386	120
Philippines (Karan)	13	Chuquisaca 7728	3474	176

Elite Experimental Variety Trials (ELVTs)

The best-performing experimental varieties across all locations are selected to form subsequent elite variety trials. In 1978, three ELVTs were assembled, and 206 sets were requested by national collaborators. One quality protein maize trial, consisting of five elite varieties (ELVT 19), also was included.

In well over half of the testing locations, our collaborators reported that the best elite varieties included in the trials outperformed the best checks at individual testing locations.

Requests for seed increase

Thirty-nine national maize programs asked CIMMYT for supplemental seed in 1979, with intentions to increase the seed for demonstrations on farmers' fields. Such a step often precedes release of a new variety. In 1979, the requests came from:

Latin America and the Caribbean, 19 countries.
Mediterranean and Mideast, 3 countries.
Africa south of the Sahara, 8 countries.
South and Southeast Asia, 9 countries.

1980 international trials

The tentative distribution of international trials in 1980 includes 816 individual trials in 85 cooperating countries. This testing network now involves virtually all developing countries in which maize is an important crop.

Distribution of international maize trials 1977-80

Region and Nation	1977 trials	1978 trials	1979 trials	1980 trials*
Central American and Caribbean	**176**	**194**	**188**	**229**
Antigua	1	0	0	0
Bahamas	2	2	4	1
Barbados	0	0	3	2
Belize	5	4	6	6
Costa Rica	11	14	12	17
Dominica	0	4	0	0
Dominican Republic	5	3	4	11
El Salvador	9	12	10	16
Grenada	1	1	1	1
Guatemala	12	16	15	20
Haiti	10	12	10	17
Honduras	12	20	14	23
Jamaica	9	13	12	9
Mexico	74	59	62	61
Nicaragua	8	12	11	10
Panama	10	19	16	25
St. Kitts	0	0	1	1
St. Vincent	0	1	1	1
Trinidad	7	2	6	8
South America	**92**	**124**	**105**	**125**
Argentina	6	6	10	12
Bolivia	13	31	11	13
Brazil	35	30	28	35
Chile	2	2	5	6
Colombia	12	15	15	8
Ecuador	8	10	10	14
French Guiana	0	2	4	4
Guyana	3	4	0	0
Peru	9	17	13	24
Surinam	1	2	4	5
Venezuela	3	5	5	4

* Tentative

Distribution of international maize trials 1977-80 (Con't)

Region and Nation	1977 trials	1978 trials	1979 trials	1980 trials*
Mediterranean/Mideast	**46**	**61**	**55**	**92**
Algeria	2	2	2	2
Egypt	13	16	7	19
Iraq	6	3	2	2
Jordan	0	2	4	4
Libya	0	0	3	11
Morocco	0	2	2	3
Saudi Arabia	3	7	6	6
Sudan	4	2	3	3
Syria	0	3	3	12
Tunisia	1	2	2	2
Turkey	4	4	3	11
Yemen A.R.	13	13	13	13
Yemen, South	0	5	5	4
Tropical and Southern Africa	**92**	**149**	**162**	**238**
Benin	1	1	2	2
Botswana	3	5	3	7
Cameroon	7	7	6	8
Central African Republic	2	2	0	0
Chad	0	3	2	2
Ethiopia	4	12	9	22
Ghana	4	4	3	9
Guinea-Bissau	3	3	3	4
Ivory Coast	10	15	10	15
Kenya	3	2	6	6
Lesotho	0	2	3	6
Malawi	4	7	6	6
Mali	0	0	4	6
Mozambique	0	17	17	22
Niger	0	0	1	2
Nigeria	12	14	26	37
Reunion	0	0	2	0
Rwanda	0	5	4	6
St. Helena	2	4	0	0
Senegal	0	9	7	13
Sierra Leone	0	0	9	15
Somalia	0	1	6	4
South Africa	8	9	4	11
Swaziland	1	1	2	3
Tanzania	12	9	9	7
Togo	1	1	1	1
Uganda	1	1	2	2
Upper Volta	2	2	3	11
Zaire	9	10	8	8
Zambia	3	3	4	3

* Tentative

Distribution of international maize trials 1977-80 (Con't)

Region and Nation	1977 trials	1978 trials	1979 trials	1980 trials*
South and East Asia	**70**	**78**	**89**	**113**
Afghanistan	2	2	4	2
Bangladesh	7	7	7	5
Burma	0	4	6	7
India	13	13	16	24
Indonesia	3	2	3	3
Korea, South	0	0	2	2
Malaysia	3	2	4	4
Nepal	8	6	12	12
Pakistan	10	10	12	22
Philippines	11	19	12	15
Sri Lanka	2	2	3	5
Thailand	11	11	8	12
Other	**1**	**15**	**16**	**19**
Greece	0	2	4	4
Hungary	1	2	2	2
New Guinea	0	7	6	6
Tahiti	0	0	3	5
Puerto Rico	0	4	1	2
TOTAL TRIALS	**477**	**621**	**615**	**816**
TOTAL COUNTRIES	**64**	**80**	**84**	**85**

* Tentative

QUALITY PROTEIN IMPROVEMENT

Beginning in 1970, CIMMYT's maize improvement program was expanded to include improvement in the nutritional aspects of maize. Today, this work is an integral part of the total maize improvement program. Various materials undergoing improvement in the Back-Up, Advanced, Special Projects and Collaborative Research units have parallel counterparts in the quality protein project.

CIMMYT scientists realized that it would be difficult to encourage the production of high-lysine maize if it yielded less than normal maize. Therefore, the emphasis was placed on improving protein quality without sacrificing yield. It also was necessary to develop high-lysine maize varieties having a normal-looking maize endosperm similar to those grown by farmers (endosperm refers to the starchy part of maize kernels). Early work at CIMMYT indicated that problems of low yield and unacceptable kernel appearance, as well as other major problems associated with soft opaque-2 endosperm, could be overcome through careful and systematic selection for vitreous hard endosperm kernels that still retained high-lysine and tryptophan contents and thus improved protein quality.

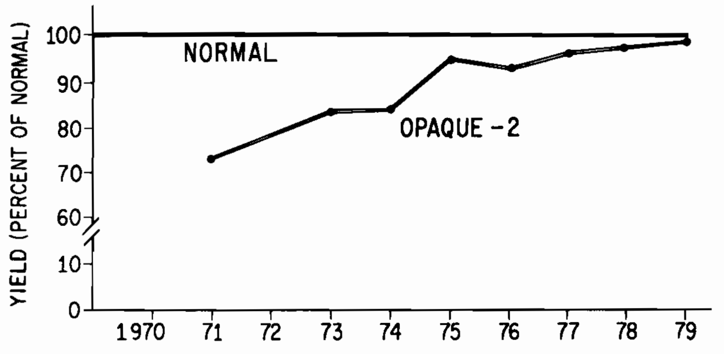
This strategy has shown that, genetically, it is possible to combine high yield and high nutritional quality in maize materials and remove the defects (e.g. lower yields and dull, chalky, soft-kernel types) normally associated with the opaque-2 gene.

Within the conversion process, the selection of genotypes with hard kernels which remain stable (i.e. do not tend to revert to soft kernels in certain environments) is a primary breeding objective. Over time, the percentage of quality protein maize materials emanating from this conversion process has continued to improve. These modified materials must be analyzed by the Protein Quality Laboratory so that families which have lost some of their protein quality can be discarded. This selection process has resulted in the maintenance

CIMMYT has developed high-yielding maize varieties that have much better protein quality than traditional maize types. These quality protein maize varieties offer considerable promise in improving the diets of traditional low-income maize consumers.

in hard endosperm types of the high protein quality levels of characteristic soft opaque-2 materials. Most of these modified materials have a lysine content of 3.5 to 4 per cent, or up to twice the level of ordinary maize types.

Grain yield of quality protein maize expressed as a percentage of normal maize check in different years across all test locations.



Yield potential of quality protein maize materials

Originally the quality protein maize materials did not yield as well as their normal counterparts. This difference was attributable to the earlier cessation of starch accumulation in high-lysine materials resulting in smaller, lighter kernels. Through recurrent selection over several cycles for hard endosperm materials with larger kernels, the yield potential of these materials has improved substantially.

During 1978, a trial was designed to compare 10 quality protein entries and their normal counterparts. The trial was conducted at three experiment stations used by CIMMYT: Poza Rica, Tlaltizapan and Ciudad Obregon. The results of this trial clearly indicate that the yield performance of the best modified versions of several CIMMYT lowland tropical populations is about equal to the normal counterparts, and some of the quality protein materials were somewhat earlier than their normal counterparts.

Opaque-2 Maize Population Trials (OMPTs)

Twenty-one of the best quality protein maize populations were assembled in 1978 into trial OMPT 11, which was planted in 44 locations in 31 countries. Data received from 20 locations growing the OMPT 11 trial show that at 60 per cent of these testing sites, the best quality protein population equaled or exceeded the yield of the best check. The data showed that the quality protein materials did not show any more disease reaction than the best normal checks. Further, the hard endosperm grain texture of the quality protein entries remained stable over a range of environments. These materials also were superior in other desirable traits, such as earlier maturity, shorter plant height and resistance to leaf diseases.

CONTINUING UNDP SUPPORT

In 1978, the United Nations Development Program (UNDP) reviewed the progress made by CIMMYT in the nutritional improvement of maize and approved financial support for another five-year period, 1979–84. In this new phase, project objectives extend beyond protein quality to include some other nutritional quality aspects of maize, such as oil content.

A panel of nutritionists has been set up to interact with CIMMYT on a continuing basis to advise on the status of nutritional research as it applies to this project.

COLLABORATIVE RESEARCH FOR RESISTANCE TO THREE MAJOR DISEASES

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

To begin this research, CIMMYT assembled three broad-based maize populations (one white dent, one white flint and one yellow flint-dent) which would have general acceptance in the tropics provided they carried stable resistance to the three diseases.

Using a shuttle breeding strategy involving alternate screenings in disease "hot spot" areas followed by an agronomic improvement cycle in Mexico, scientists are making good progress towards developing maize populations with resistance to downy mildew and to corn stunt. Pictured above are maize materials with varying degrees of resistance to corn stunt.

Each year CIMMYT sends to the collaborating countries several hundred progenies from these base populations for screening under disease conditions. Seeds from superior plants in families showing resistance are returned to Mexico and improved for general agronomic characteristics. This technique of shuttle breeding is proving to be an extremely efficient breeding strategy to rapidly develop high-yielding varieties with greater disease resistance.

In 1980, the project entered its fifth cycle of selection for resistance to stunt and to downy mildew and the fourth cycle of selection for streak resistance.

In 1979, the superior families with resistance to downy mildew and corn stunt were internationally tested for the first time for yield potential and disease resistance. The results indicate that good progress has been made in increasing the resistance to downy mildew and corn stunt.

The progress on streak virus has been slower. The lack of insect-rearing facilities (streak virus is disseminated by a leaf hopper) located in virus-affected areas for disease screening and uniform inoculation is hampering this research effort.

SPECIAL RESEARCH ACTIVITIES IN MEXICO

Within CIMMYT's general maize improvement program, new ideas and techniques for improving specific characteristics of the maize plant are studied on a special project basis. In these projects, the researcher confines the study to one or a few populations. Four such special studies are now under way dealing with yield efficiency in tropical maize, drought tolerance, early maturity and wide adaptation. These studies may require many years for completion, but the conclusions reached may ultimately be applied to other parts of the program.

Yield efficiency in tropical maize

The development of tropical and subtropical plant types that produce a greater proportion of their total dry matter in the form of grain, rather than leaves and stem, is a basic objective in the overall maize program. Different approaches to achieve the objective, such as the shortening of the tropical maize plant and reducing the leaf area and tassel size, are being investigated.

Research at CIMMYT has shown that the grain efficiency of tropical maize can be modified towards the more efficient partitioning (grain vs stover) characteristics of high-yielding temperate maize materials.

CIMMYT scientists, using the lowland tropical population Tuxpeño, have been selecting within the population for shorter plant height. By the end of 1979, 18 cycles of selection had been completed, and plant height had been reduced to approximately 50 per cent of that of the original material.

As the Tuxpeño population plants have become shorter, they have also become earlier. In addition, yield under good management conditions has increased substantially, particularly when the plant density is increased. Yield increases are attributed to less lodging and fewer barren plants and to an improved partitioning (harvest index) of dry matter to grain in the shorter plant selections. While the more efficient short-plant type is clearly advantageous, the higher plant density requirement also means increased seed and more work in planting where hand labor is used. Further studies are being designed by national collaborators to look at some of the agronomic implications of these shorter and earlier plant types.

Starting in cycle 12, the researchers began selecting separately in the Tuxpeño population for two other characteristics associated with yield efficiency: reduced tassel size and reduced leaf size. Two other populations unrelated to Tuxpeño are also being subjected to similar studies. Preliminary yield tests point to the improved grain efficiency of selections with reduced foliage and tassel size; however, further testing is needed to verify these results.

Crosses of tropical and temperate germ plasm have been shown to be more efficient in grain production than the tropical material but are less tolerant to tropical diseases and pests. It may be possible, by continual and simultaneous selection for both yield efficiency and pest tolerance, to adapt these potentially higher-yielding tropical-temperate materials to tropical conditions. Two such populations continue to be improved toward these objectives.

Drought tolerance

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

A special project initiated in 1977 to develop techniques capable of identifying drought tolerant genotypes indicates that it is possible to select genotypes with improved yielding ability under drought stress conditions without losing their capacity to perform well under adequate moisture conditions.

A number of criteria have been identified which are reasonable indicators of the ability of a particular genotype to perform better than average under water stress conditions. A selection index incorporating these criteria as well as grain yield (under non-stress and stress conditions) was used to identify 80 superior families in 1979. These families were then recombined and will be tested again in 1980.

Earlier maturity in tropical maize

Many tropical maize-growing countries need good yielding varieties which mature earlier to fit into a brief rainy season or a tight cropping sequence. The sacrifice in yield and disease susceptibility associated with very early maturing varieties has been long recognized as the major breeding problem in developing these types.

A special project is utilizing alternative approaches to develop genotypes with earlier maturity and good yield. In one approach, high-yielding intermediate tropical types have been used to form a population from which selection is made for earliness. Eight cycles of selection have been completed to the end of 1979.

A trial to measure the change in yield and maturity in selected families is planned for 1980. In such selections for earliness, the breeder may be able to reduce either the time to flowering or the duration of the grain-filling stage. A student research project was initiated in 1978 to evaluate the relative importance of these two development stages to grain yield. It is anticipated that such information can be useful to breeders in their selection procedures.

Another approach consists of assembling earlier maturity genotypes from wherever they are encountered, and then to improve their yield and disease and insect resistance. A yield trial conducted in 1979 indicates that superior families can be identified for high-yielding ability within early populations.

Wider adaptation

The development of broadly adapted germ plasm is a concept basic to all CIMMYT improvement programs. To see how far this idea can be extended in maize, a special project is developing a unique germ plasm pool.

In 1980 CIMMYT makes its 13th cycle of recombination in a maize population drawn from many temperate and tropical climates. Initially the cold climate materials would not set seed in the lowland tropics, and vice versa, because of sensitivity to differing day lengths, temperatures and diseases. Today this population sets seed in a range of maize-growing environments.

This special project in wide adaptation serves several ends: first, a widely adapted population can be used to transmit wide adaptation to other populations; and second, wide adaptation in a parent can serve as a vehicle for transmitting genotypes with a broad gene base almost anywhere in the world.

Combining ability of CIMMYT germ plasm

Relatively little information is available about the suitability of CIMMYT populations for the development of hybrids. Such information would be useful for further improvement of the populations and for those national collaborators interested in hybrid development. To gather this information, all CIMMYT materials are being crossed to Eto Blanco and Tuxpeño, two varieties that are known to combine well and produce good hybrids. Most of these crosses were accomplished in 1979, and the remaining combinations will be completed in 1980. Yield trials will be conducted at CIMMYT stations in Mexico in the summer of 1980.

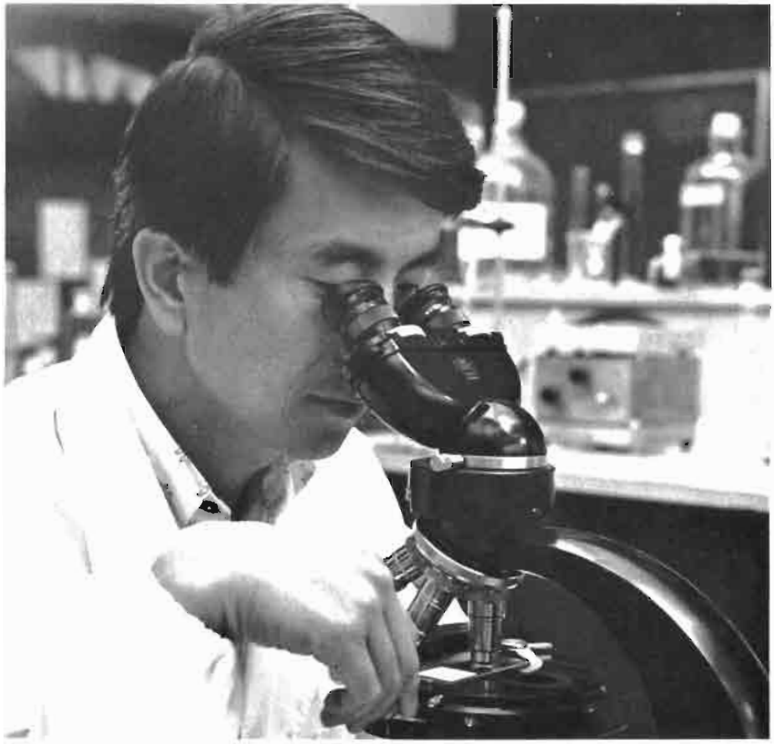
WIDE CROSSES

Crosses between maize and two alien genera, sorghum and *tripsacum*, continue as part of the maize improvement program to determine if it is possible to make available to maize the potentially useful genes from these genera. In general, the aim is to make maize a more environmentally stable crop; (i.e., with better insect and disease resistance from *tripsacum* and more drought tolerance from sorghum).

Maize x tripsacum crosses

During 1978-79, approximately 14,000 crosses were made between maize and *tripsacum*, and 15 hybrids were obtained.

Eleven of these were classical hybrids that retained the



CIMMYT scientists continued their wide-cross and cytological research in 1979 to transfer useful genes from genera alien to maize in hopes of adding greater environmental stability to the tropical maize plant.

expected gametic number of chromosomes from both parents. In appearance, they resembled *Tripsacum* more than maize and were perennial. The other four were non-classical hybrids, having 20 maize chromosomes and various numbers of *Tripsacum* chromosomes in different root tip cells. These hybrids were more maize-like in appearance and were annual.

Maize x sorghum crosses

During 1978-79 over 23,000 crosses were made between maize and sorghum, and nine hybrids appear to have been obtained. All nine hybrids were non-classical types, as described above for maize x *tripsacum* crosses. These plants were more maize-like in appearance, and all flowered within seven months of germination. All had tassels that were reduced in size, with only one, or very few, branches. No hybrid had viable pollen. Six set some seed when crossed back to maize.

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
  production agronomy
  maize improvement
  laboratory analysis
  experiment station management

—Graduate student programs in cooperation with universities. Some students spend 12 to 18 months in Mexico to do thesis research.

—Postdoctoral fellows: 2 years service at CIMMYT.

—Visiting and Associate scientists: up to 1 year fellowships at CIMMYT.

In-service

The in-service training program in maize is nine years old,

The in-service training courses for production specialists are central to CIMMYT's efforts to assist national programs in staff development. On-farm research which integrates the perceptions of economists, biological researchers and farmers toward the common goal of devising more appropriate production recommendations is the focus of these training courses.

and nearly 500 participants from more than 50 countries have passed through the six-month course. Originally, the emphasis was more on maize improvement. Today, however, about 7 out of 10 specialize in production agronomy.

The production training program emphasizes on-farm research. In addition to long hours of field work associated with on-farm surveys and experiments, the trainees are introduced to strategies for organizing production research systems.

In the maize improvement course, trainees are exposed to the range of breeding materials undergoing improvement at CIMMYT. Each participant is involved in all aspects of maize improvement at different experiment stations used by maize program staff in Mexico. This practical training is interspersed with participation in the production research experiments and classwork related to the various breeding methods used by CIMMYT in maize improvement.

Maize in-service trainees 1971-79

Region and Country	1971-79	1979
Central America and Caribbean	**150**	**27**
Belize	5	0
Costa Rica	10	4
Dominica	1	0
Dominican Republic	11	2
El Salvador	22	1
Grenada	1	0
Guatemala	15	1
Guyana	1	0
Haiti	11	2
Honduras	24	1
Mexico	22	7
Nicaragua	16	5
Panama	11	4
South America	**76**	**12**
Argentina	11	0
Bolivia	10	2
Brazil	3	0
Colombia	9	1
Chile	2	0
Ecuador	17	3
Peru	17	5
Venezuela	7	1
South and East Asia	**107**	**18**
Afghanistan	6	2
Bangladesh	5	3
India	9	2
Indonesia	3	0
Japan	5	0
Korea	2	0
Malaysia	1	1
South and East Asia (Con't)		
Nepal	18	0
Pakistan	23	2
Philippines	18	1
Thailand	17	7
N. Africa and Mideast	**31**	**3**
Algeria	1	0
Egypt	15	1
Syria	1	0
Tunisia	3	0
Turkey	8	2
Yemen A.R.	3	0
Tropical Africa	**118**	**12**
Botswana	1	0
Cameroon	1	0
Ethiopia	3	0
Ghana	8	2
Ivory Coast	4	0
Kenya	3	0
Malawi	1	0
Nigeria	12	0
Rwanda	1	0
Senegal	1	0
Tanzania	50	4
Uganda	1	0
Zaire	28	6
Zambia	4	0
Other	**2**	**0**
Total training fellows	**484**	**72**
Total countries	**53**	**26**

Graduate student training and doctoral fellows

During 1979–80, CIMMYT is sponsoring the training of ten master's degree candidates (Bolivia, Costa Rica, Colombia, Tanzania and Zaire); three predoctoral fellows (Zaire) and two postdoctoral fellows (Colombia, Vietnam).

Visiting scientists

During 1979, the maize programs received 53 visiting and associate scientists and 42 short-term visitors. Visiting scientists spend from a few weeks to one year in Mexico. Short-term visitors are often agricultural policy makers and administrators who usually spend a week at CIMMYT.

MAIZE COOPERATIVE PROJECTS OUTSIDE MEXICO

In 1979, scientists from most maize-growing countries of the world cooperated with CIMMYT scientists in germ plasm development and exchange of research information. A few individual countries in the network have asked for direct staff assistance and CIMMYT has received special funds to provide this collaboration. A number of regional programs have emerged among various maize-growing countries, and CIMMYT has posted staff to support these regional efforts. At the end of 1979, 14 staff were assigned to either national or regional programs, as described below.

National programs

CIMMYT staff were working within five national programs at the end of 1979. These staff work on a daily basis with national program counterparts in all aspects of national maize research, production, staff development and training.

Cooperative projects involving national programs, 1979

Country	Start of CIMMYT arrangement	CIMMYT staff assigned	Donor
Zaire	1968	1	Zaire
Tanzania	1973	2	USAID/IITA
Guatemala	1976	2	USAID
Pakistan	1979	1	USAID
Ghana	1979	1	CIDA(Canada)

CIMMYT has had staff assigned to the Guatemalan national maize program of the national agricultural research institute (ICTA) since 1976. This program has made a significant impact on lowland maize production, due in large part to a certified seed production and marketing system which harnesses the energies of both the public and private sectors to reach the farmer.

Regional programs

A regional maize program helps forge stronger linkages among national collaborators and with CIMMYT. Regional programs generally comprise neighboring countries in which maize is a major crop (or has the potential of being one) grown under similar climatic conditions and exposed to similar diseases and insects. Therefore these countries benefit from closer collaborative research, training and information links.

Regional maize programs in 1979

Region and operations base	Number of cooperating countries	Start of CIMMYT arrangement	CIMMYT staff assigned	Current Donor
Central America and Caribbean (Mexico)	13	1974	2	Switzerland
South and Southeast Asia (India)	11	1976	1	UNDP
Andean countries (Colombia and Ecuador)	5	1976	3	CIDA (Canada)
Mideast	9	1979	1	Core Unrestricted

Central American and Caribbean regional program

The efforts of the maize staff assigned to this region are aimed at strengthening national research and production programs by helping individual countries to develop and deliver more appropriate production technologies to local farmers.

Regional staff assisted in conducting international trials tested within the region in 1979. Particular emphasis was placed on the identification of materials with good husk cover and low incidence of ear rots. Considerable progress toward these objectives is being reported from Costa Rica, Guatemala, Honduras and Panama. These countries have released new improved varieties, and farmer demand for these materials is strong.

On-farm research is receiving increasing support among regional scientists. Several countries have made a strong commitment to this type of research. Various cropping sequences and associations are being studied. The need for earlier-maturing high-yielding maize materials is emerging as an important germ plasm requirement for the region. Weed control is another major area of research activity. Minimum tillage methods are being tested, in the context of monocropping, relay or association patterns of productions.

A number of training assistance activities were carried out in 1979 by the regional staff, who participated in breeding methodology and on-farm research short courses in Costa Rica, the Dominican Republic and Honduras. In addition, 20 young scientists from the region completed in-service training courses at CIMMYT in 1979.

South and Southeast Asia regional program

Since 1976, CIMMYT has maintained one breeder/agronomist based in India to assist in the improvement of germ plasm for the region, to encourage national on-farm research activities and to improve the exchange of research data and ideas among area scientists.

Considerable need exists to develop earlier and more disease-resistant materials for this region. In addition, the market demand for maize must be strengthened in many countries before increased production will occur. Toward this end CIMMYT cosponsored with the Indian Council of Agricultural Research (ICAR) an international workshop in New Delhi on maize utilization, processing and marketing in mid 1979.

Eighteen scientists from eight countries in the region completed in-service training courses at CIMMYT during 1979.

Andean regional program

CIMMYT has three staff assigned to this region. One breeder is assigned to Ecuador where he collaborates with national breeders from the region on improving maize varieties for highland areas. A Mexican cultivar, Cacahuacintle, is showing considerable advantage in the highland areas. This variety is high-yielding, has better disease resistance and is about two months earlier than traditional materials. It can permit a second short season crop in some areas. National scientists expect this material to have a substantial impact on floury maize production in the Andean highlands in the years ahead.

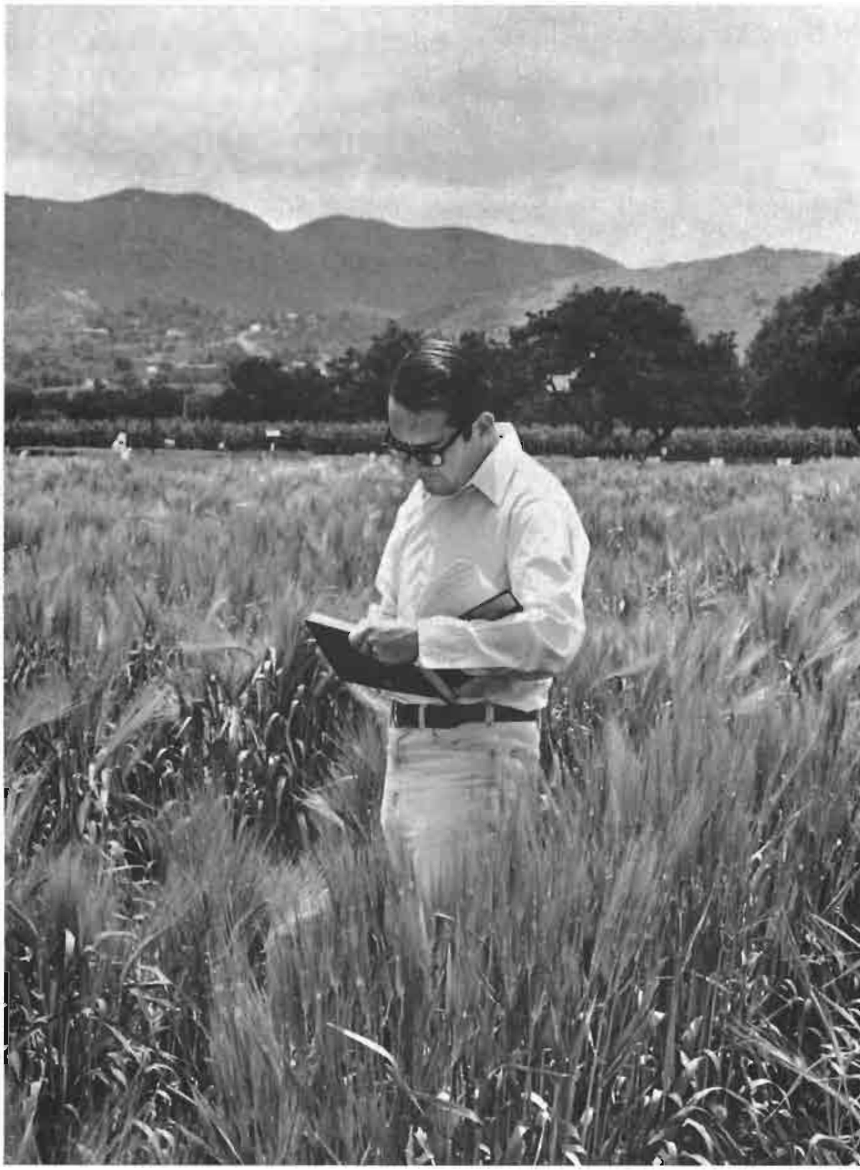
Some CIMMYT populations have shown superior performance in the lowland tropical areas of the Andean regions. These materials are receiving good acceptance and varieties are being released by national programs.

In 1979, 12 scientists from the region completed in-service training courses at CIMMYT.

Mideast regional program

In late 1979, the maize breeder/agronomist assigned to Egypt was shifted to a regional assignment, with his center of operations located in Turkey. Special breeding priorities will include the development of maize materials with greater resistance to late wilt, and also to stem borers. In 1979, three scientists from the region completed in-service training courses at CIMMYT.

wheat improvement



INTRODUCTION TO WHEAT PROGRAM

For many collaborating countries, 1979 brought record (or near-record) harvests. Among these were India, Pakistan, Bangladesh, Turkey and Argentina. New varieties carrying CIMMYT germ plasm were released by a considerable number national institutes.

The start up of the Southern Cone regional program was an important new addition to the regional linkage system with national collaborators. Considerable emphasis is being placed on ways to improve wheat production in tropical soils characterized by problems of acidity, high aluminum concentrations and high phosphorus fixation tendencies.

The 4th Regional Wheat Workshop, hosted by the Algerian government and cosponsored by CIMMYT and ICARDA, was held in Algiers in 1979. Conference participants focused on the production constraints facing wheat farmers in the Mediterranean and Mideast regions. Many of the issues raised in this conference will serve as orientation to CIMMYT's work in production agronomy research.

The progress being made by the network of collaborating scientists and the production records being set by developing country farmers provide CIMMYT staff with strong reasons for optimism about the potential for continued increases in wheat production as we enter the 1980s.

In the pages which follow, the highlights of the 1979 wheat program activities are presented. Despite heavy frost damage to the summer CIMMYT nurseries that prevented harvesting of much of the material, 1979 was a successful year for the wheat improvement program.

R. Glenn Anderson

WHEAT SUMMARY

Bread wheat

CIMMYT continued to work in 1979 on developing broadly adapted, high-yielding cultivars. Breeding emphasis was given to spring x winter crosses, multiline component development based on cross 8156, greater disease resistance, enhanced aluminum toxicity resistance in certain lines, development of earlier high-yielding materials and wheat for the humid tropics. National collaborators in 19 countries reported the release in 1979 of more than 50 varieties to local farmers which carried CIMMYT-distributed germ plasm in their parentage.

Durum wheat

Through an intensive breeding effort, CIMMYT's advanced durum lines now yield similarly to (or slightly exceed) the best bread wheats. Continued breeding emphasis in 1979 was placed on developing greater disease resistance, improved straw strength and leaf characteristics, added cold and drought tolerance, greater earliness in high-yielding types and improved industrial quality. Collaborators in six countries reported the release of eight varieties which carried CIMMYT-distributed germ plasm in their parentage.

Triticale

High-yielding triticale lines continue to be improved in 1979 for seed type and test weight. Breeding objectives also include a widening of the triticale germ plasm base and exploratory research on the potential of octoploid (bread wheat x rye) triticale types. In 1979, national collaborators in seven countries reported 13 new commercial releases of varieties which carried CIMMYT-distributed germ plasm in their parentage.

Barley

CIMMYT's advanced barley lines showed continued improvement in 1979 in their yielding ability and breadth of adaptation. The breeding emphasis continues to be on barleys for human consumption. Added emphasis is being given to developing greater disease resistance and earlier types capable of high yields. Improved nutritional quality remains an important breeding goal. In 1979, national collaborators in three countries reported that they had four varieties carrying CIMMYT-distributed germ plasm in their pedigrees which were in the final certification stages before being released as commercial varieties.

Special germ plasm development

Special breeding research continued in 1979 to determine if the average protein content in bread wheat could be increased, to develop added disease resistance in selected high-yielding lines, to increase the yield potential in high-yielding materials through larger, more grain-filled heads and to support other research to develop greater aluminum toxicity tolerance in selected lines. This unit is placing greater emphasis on wide cross research directed at transfering useful genes into and among CIMMYT's four small grain crop species.

Agronomy

CIMMYT is placing increasing research emphasis in the field of agronomy. Much of this research will be coordinated by regional program scientists. Agronomy research at headquarters focuses on ways to improve CIMMYT's nursery management and supports agronomy training activities, both for CIMMYT scientists and in-service trainees.

Pathology

CIMMYT wheat pathologists continued to provide supporting information to the wheat, triticale and barley improvement programs. Pathologists are responsible for inoculating and evaluating lines in nurseries grown in Mexico. Headquarters-based pathologists help support CIMMYT regional pathologists and national collaborators in the screening of resistant materials. The pathology group also participates in the in-service pathology training courses.

International testing

In 1979, collaborating scientists in 115 nations requested nearly 2,300 trials of wheat, triticale and barley from 38 different CIMMYT-distributed nurseries. Central to this international testing program are the screening and yield nurseries which serve to distribute new germ plasm to collaborators and to accelerate worldwide progress in wheat, triticale and barley improvement.

Milling and baking laboratory

In 1979, this laboratory tested more than 20,000 grain samples of bread wheat, durum wheat and triticale lines. These lines are evaluated for their suitability in making bread, pasta and other products.

Wheat training

In 1979, a new in-service training course on irrigated agronomy was added to the wheat training program. In total, CIMMYT now offers seven in-service training courses each year of use to agricultural scientists engaged in wheat-related research and production activities. Other types of training programs were offered to visiting scientists and doctoral fellows.

Wheat cooperative projects outside Mexico

In 1979, one CIMMYT wheat scientist was assigned to the national wheat program in Pakistan and seven scientists were working in regional programs in Asia, Africa and Latin America. Regional nurseries are distributed in most regional programs. Considerable emphasis in all these programs is being given to production agronomy research.

BREAD WHEAT

Introduction

The total area in the developing world seeded to high-yielding varieties (HYVs) which carry CIMMYT germ plasm in their pedigrees has increased steadily during the past decade. In 1979 the total cropland area seeded to HYVs equaled 30 million hectares.

Germ plasm development

In order to continue the flow of broadly adapted, disease-resistant HYVs to national programs, CIMMYT has an extensive network of Mexico-based, regional and collaborative research programs for germ plasm screening and development.

Spring x winter wheats

CIMMYT, working in cooperation with Oregon State University (OSU), is involved in transferring useful genes between spring and winter wheats, with the aim of improving both of these major bread wheat types. Through this crossing program, such improvements as greater disease resistance, and drought tolerance in high-yielding types are becoming increasingly evident.

In this cooperative effort, CIMMYT experiment stations in Mexico and OSU experiment stations in Oregon are used for the crossing programs. The climatic conditions at Toluca, Mexico, are cold enough during the winter to facilitate natural vernalization in winter wheats from a direct November seeding. In January, spring types are planted, bringing both the winter and spring wheats to flowering in May when about 1,500 spring x winter crosses are made. The seed from the crosses is divided equally with OSU. Advanced lines selected from spring x winter crosses grown in Mexico and Oregon are distributed through international nurseries.

Several spring x winter crosses are showing high yield potential. Notable among these advanced lines are "Veery" and "Bobwhite." Many of the Veery selections were the highest yielding lines in the 1978–79 yield trials in Ciudad Obregon, Sonora.

In 1979, advanced spring x winter lines made up more than 25 per cent of the high-yielding lines in the 13th International Bread Wheat Screening Nursery (IBWSN 78–79). Many of these spring x winter lines also have the highest resistance ratings to stripe rust and *Septoria.* Current resistance levels in these materials are such that they can provide the crop with good protection except under exceedingly heavy *Septoria* infection.

The evidence continues to mount that spring x winter wheats carry greater drought tolerance than the normal spring x spring crosses. To test this apparent tolerance, a special yield trial was distributed in 1980 for testing in several drought-susceptible areas.

Spring x winter bread wheat crosses are now among the highest yielding lines in the CIMMYT program. Some lines, such as Veery, have been the top entry in recent yield trials in northwest Mexico, and also appear to have greater tolerance to drought.

Facultative wheats

Some wheat-producing areas of the world—such as Argentina, North Africa and the higher elevations of the Mideast—require spring wheats with greater cold tolerance to withstand late spring frosts. These are called "facultative wheats," and their improvement is receiving some research attention at CIMMYT. The progeny of those spring x winter crosses with a relatively longer vegetative cycle are selected for further crossing. These types appear to have added cold tolerance and adaptation for areas where true spring types often are damaged at heading time by late frosts.

8156 multiline varieties

Multiline cultivars are mechanical mixtures of agronomically similar plant types (resembling each other in plant height, maturity period and grain appearance) but differing genetically in rust resistance.

Since 1971, CIMMYT has been working with some national collaborators to develop high-yielding components for a multiline composite variety based on cross 8156 made in 1955. Varieties derived from cross 8156 have been grown on millions of hectares in the subcontinent for more than 10 years. They have become susceptible to prevailing biotypes of leaf and stripe rust. However, many farmers would again like to grow these types.

With vast areas planted to a single variety, the potential damage to the wheat crop can reach disastrous proportions if the prevailing race of a rust pathogen mutates. With the multiline variety, chances are that only one or two of the 10 to 12 component lines would become susceptible, thus eliminating the potential of a serious and widespread disease outbreak.

CIMMYT's involvement in multiline breeding includes the development of possible components for multiline varieties and distribution of these lines to interested nations for local screening and selection. In 1979—80, the International Multiline (8156) Nursery was distributed to 60 testing locations in areas of 8156 adaptation.

India multilines

Two collaborating Indian institutes, Punjab Agricultural University at Ludhiana and C.S.A. University of Agriculture and Technology at Kanpur, have released two multiline varieties, "KSML-3" and "Bithor," respectively. A third, KSML-11, has been distributed from the coordination unit of the wheat program. Two varieties make use of CIMMYT components in their composite make-up.

Aluminum toxicity resistance

There are areas of actual or potential wheat production, for example, Brazil and East Africa, which have acid soils and aluminum toxicity problems. A cooperative research program was initiated in 1973 with three Brazilian institutes (EMBRAPA, FECOTRIGO and OCEPAR) to transfer resistance to aluminum toxicity into high-yielding, disease-resistant semidwarf wheat types.

A shuttle breeding strategy has been followed in which CIMMYT crosses are sent to Brazil for evaluation of aluminum toxicity resistance. The resistant lines (segregates) are returned to Mexico, where selection for high yield and rust resistance is made at Ciudad Obregon. This shuttling between Mexico and Brazil allows two seasons per year with alternate selection under high-yield conditions and aluminum toxicity situations.

The objectives of this program to transfer aluminum toxicity resistance into superior agronomic types have been largely accomplished. Over 100 different lines (crosses) have been developed which combine aluminum toxicity resistance with good yielding ability. The focus is now on enhancing disease resistance needed in these lines to maintain high and stable yields.

Disease resistance

Breeding for disease resistance, especially to stem, leaf and stripe rusts, is an integral part of CIMMYT's research program. Various locations in Mexico, known for the presence of some damaging wheat diseases, are used as sites for the selection of lines exhibiting resistance.

The IBWSN continues to be a major mechanism to identify and distribute lines with broad resistance to wheat diseases. In addition, a number of more specialized international nurseries (e.g. for *Septoria, Helminthosporium*) and regional nurseries (Regional Disease and Insect Screening Nursery, (RDISN), and Latin American Wheat Disease and Observation Nursery, VEOLA) have been developed. These nurseries broaden the base for identifying germ plasm resistant to wheat diseases. Particular attention is being placed on improving the resistance of all CIMMYT materials to *Septoria* and *Helminthosporium.* CIMMYT is cooperating with national programs in Ethiopia, Israel and countries in North Africa where excellent screening and evaluation of *Septoria* are possible. Collaborative research on *Helminthosporium sativum* is also under way with Bangladesh, India and Zambia. In both of these collaborative research projects, screening is done in disease-susceptible areas, followed by specific crossing programs in Mexico to pyramid genes conferring disease resistance into materials with good agronomic characters.

Wheat for the humid tropics

A number of wheat-importing countries situated in the tropics—notably those in Central America, coastal South America, West Africa and Southeast Asia—are interested in growing wheat in their winter season, the period of coolest temperature and lowest humidity, as a means of reducing foreign exchange outlays for imported wheat.

A serious disease under these humid tropical production conditions is *Helminthosporium sativum.* Over the last several years, CIMMYT has evaluated thousands of advanced lines and breeding populations at our Poza Rica experiment station, located in the coastal plain of the State of Veracruz. During the last two years, many advanced lines have been identified which have some level of tolerance to this disease.

Crosses have been made with these lines, and the F_2 (first generation after cross) will be sent to Zambia (where *Helminthosporium* is endemic) and other locations for screening. Resistant selections will be shuttled between these centers and Ciudad Obregon, Sonora, Mexico, for selection under both high-disease and high-yield environments. The most promising materials were distributed in 1979 through the Tropical Helminthosporium Screening Nursery (THSN) to collaborators for testing at 29 locations around the world.

Wheats with early maturity

Early-maturing wheat varieties are needed in certain areas (India, Pakistan, Nepal, Bangladesh, South Korea, China) to fit rotation patterns with other crops. Past selection criteria for high yield and broad adaptation have often resulted in full-season crops with relatively late maturity characteristics. Some of the earliest germ plasm is found in Korean and Chinese wheats, and these have been crossed with the earliest CIMMYT lines. Segregating populations of these crosses, which have suitable agronomic characters, high-yield potential and disease resistance, are shuttled between South Korea and Mexico to select for early maturing lines at both locations.

In 1978–79 at Ciudad Obregon, 58 advanced lines with early maturity were compared in yield trials to INIA 66 (a relatively early variety) with 11 lines equal in yields and maturity characters to INIA 66.

International testing

In 1979, the following international nurseries were prepared for distribution to bread wheat collaborators:

Nurseries	Lines	Sets
THSN – Tropical Helminthosporium Screening Nursery	22	35
F_2 Irrigated	569	60
F_2 Dryland	673	60
F_2 8156-types	108	60
F_2 Aluminum	104	60
F_2 Spring x Winter	485	110
CB – Crossing Block	434	50
IBWSN – International Bread Wheat Screening Nursery	530	300
ISWYN – International Spring Wheat Yield Nursery	50	120
ESWYT – Elite Spring Wheat Yield Trial	30	30
ISEPTON – International Septoria Observation Nursery	177	50

Varietal releases

Materials emanating from this testing system were named and released by 19 collaborating countries for use by local farmers in 1979. Some of the countries reporting and the number of CIMMYT-related varieties released were:

Argentina (5)
Australia (3)
Bangladesh (2)
Bolivia (1)
Brazil (5)
Canada (1)
Chile (1)
Cyprus (2)
Ethiopia (1)
Egypt (3)
India (12)
Kenya (3)
Korea (1)
Madagascar (2)
Mexico (3)
Mozambique (1)
Nigeria (1)
Pakistan (6)
Rumania (1)

Selected spring bread wheat varieties bred by CIMMYT, INIA or predecessors, released in Mexico, 1950-79

Year of Mexican release	Variety name	Year of cross	Yield potential kg/ha*	Plant ht cm	Grain color	Disease rating in Mexico 1979** 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	7500***	90	Amber	0	TMR	10MR	S
1976	Pavon 76	1970	7500***	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	7500***	90	Red	5MR	TR	TR	S
1979	CIANO 79	1974	7500***	90	Red	TR	TR	TR	S
1979	Imuris 79	1974	7500***	90	Amber	TR	TR	TR	S
1979	Tesia 79	1973	7500***	90	Red	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 1976-79 has ranged 7500-9500 kg/ha in different seasons and trials, but the conservative minimum of 7500 kg/ha is given here for all five releases.

DURUM WHEAT

Introduction

Durum wheat is grown extensively in the Mediterranean region, the Mideast, India, the Andean countries, Argentina, Chile, USSR, Canada and USA. Semolina (from durum wheat) is generally used for macaroni, spaghetti and other pasta products, and for flat-unleavened bread in the Mideast countries: couscous in North Africa, chapatis in India, freke in Syria, bulgar in Turkey and mote in the Andean countries. Worldwide, durum is grown on about 30 million hectares, often under rainfed conditions and with low average yields (less than 1,000 kg/ha).

CIMMYT's formal entry into durum improvement began in the late 1950s with the predecessor organization and was expanded in 1968, when a durum breeder was appointed. At that time, few high-yielding, disease resistant varieties with good industrial quality were available for release to farmers in developing countries.

While considerable progress has been made in durum breeding, some varietal traits still need additional improvement, such as greater resistance to certain diseases, earlier maturity and greater resistance to lodging. CIMMYT believes that continued improvements in these general characters can have a considerable impact on raising the average yields of durums grown in collaborating countries.

Yield potential

Previous problems of sterility in dwarf and semidwarf durums have been diminished significantly, and the higher-head fertility of newly developed lines now is maintained in summer and winter plantings. In terms of yield potential, CIMMYT's advanced durum lines now yield similarly to or slightly exceed the best bread wheats.

Disease resistance

Although considerable progress has been made in improving the general levels of resistance of durums to the three rusts—stripe, stem and leaf—resistance levels need to be strengthened further for certain durum-growing areas of the world. In particular, greater stem rust resistance is needed, and CIMMYT is planning a collaborative research project on durums with countries where virulent forms of stem rust exist, which allows for good selection pressure. In addition, the Kenyan National Wheat Program has developed a stem rust parental collection of resistant materials, which is distributed via CIMMYT to several African, Mideast, Asian and South American countries for use in national crossing programs to increase still further the genetic resistance to this disease in locally grown cultivars.

Additional resistance to *Septoria, Fusarium* head scab, and *Helminthosporium* is also being pursued. Several specialized nurseries and cooperative projects are being planned. Regional nurseries are also screened for *Septoria* resistance. In addition, CIMMYT scientists are collaborating on this problem with national program scientists in Ethiopia, Kenya and Israel.

Research on *Fusarium* head scab, a problem with durum wheat in cool climates where a maize/wheat rotation is followed, is under way with collaborators in Argentina and Brazil.

Cold tolerance

Although durum wheats are grown mainly in cold-free areas, in some important production areas in the Mediterranean, Mideast and South America regions, sub-freezing temperatures may occur, usually during the early stages of growth. During the 1978–79 season, CIMMYT planted in Toluca 2,507 lines and cultivars obtained from the USDA-World Durum Wheat Collection. These lines were subjected to below-zero temperatures. Some promising materials were identified, and a group of cold-tolerant lines was distributed to interested collaborators for planting at 50 locations during 1979–80. Crosses are being made between the facultative "winter" type triticales (primarily of Turkish origin) and spring-habit durum wheats.

Early and drought-tolerant materials

The durum program is receiving some early-maturing and drought-tolerant germ plasm from several cooperating programs. These two groups are being used in the crossing programs at CIMMYT. In 1979, CIMMYT distributed 50 sets of F_2 progeny of these materials for screening in selected dry areas.

Improving straw strength

Durum materials with greater straw (stem) strength are being requested by collaborators. Areas where heavy competition with weeds and low-input cropping exist also require taller varieties, which in turn necessitate the presence of good straw strength. Advanced lines of various heights with stronger straw have been developed and distributed in 1979 to interested cooperators.

CIMMYT's advanced durum lines now have high yield potential, good industrial quality and broad adaptation. Varieties carrying CIMMYT germ plasm in their pedigrees are now grown widely in Mediterranean basin countries and in South America.

Improving leaf area and position

The restructuring of the leaf area and position in traditional durum plant types toward one with shorter, narrower upright leaves can offer improvements in the efficiency of plant utilization of water. Since durums often are grown in water-short areas (North Africa, Mideast), this physiological improvement can add to the yield dependability of the crop.

During 1979, breeders continued to identify lines with upright leaves and/or short narrow leaves. These lines are being used in crosses with high-yielding, early, good-strawed, disease-resistant durum types. It is hoped that this part of the program will gradually alter the plant architecture of future HYV durum lines.

Breeding for long-lax and semi-lax heads

This research effort is directed toward developing durum heads with greater spacing between spikelets, which offers the following advantages:

(1) better and faster drying after rainy or wet weather (reduces susceptibility to head diseases);
(2) gives room for larger, plumper grains to develop (which improves the industrial quality of the grain); and
(3) better fertility and yield potential.

Industrial quality

Although about half of the world's durum wheat production is used for home consumption, a number of developing countries are in a position to produce durums for export to Europe and other regions. To be readily marketable, these durum wheats must have a high grain test weight, large size grains and good macaroni color.

CIMMYT's cereal quality laboratory routinely screens new high-yielding lines to help identify parents which do not lose quality characters during macaroni processing. Today the carotene content in many CIMMYT lines compares favorably with the best Italian macaroni durums.

International testing

In 1979, CIMMYT distributed 382 nursery sets for worldwide testing. The following different international durum nurseries were prepared for distribution to national collaborators:

Nursery	Lines	Sets
F_2 – Irrigated	295	45
F_2 – Dryland	461	52
F_2 – Cold Tolerant	67	46
CB – Crossing Block	181	42
IDSN – International Durum Screening Nursery	169	101
IDYN – International Durum Yield Nursery	50	96

New releases

In 1979, the number of new varieties released in national programs, and carrying CIMMYT germ plasm in their parentage, were as follows:

Egypt (1)
Kenya (3)
Libya (1)
India (1)
Mexico (1)
Rumania (1)

Durum varieties released in Mexico between 1960 and 1979.

Year of Mexican release	Variety name	Year of cross	Yield potential* kg/ha	Plant ht.* cm	Disease reaction** Stem rust	Disease reaction** Leaf rust	Disease reaction** 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, 1975. R=resistant, MR=moderately resistant, MS=moderately susceptible, S=susceptible. Figures before letters indicate percentage of infection.
*** Carotinoids.

TRITICALE

CIMMYT continues its work on the manmade crop triticale—a cross of wheat and rye. Despite the clear production potential of triticale for certain developing country environments, most of the approximately 360,000 hectares currently in production is in the developed countries. CIMMYT considers that it is logical for these developed countries to be the first to enter into commercial triticale production, since they are better able to carry out the adaptive research required to get triticale into use.

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

Triticale has shown greater dry matter production than wheat, and further partioning to grain (versus straw) may push the maximum yield potential of triticale to higher levels than those attainable in wheat.

The CIMMYT triticale program, since its formal initiation in 1968, has continued to improve triticales so they will be acceptable as a commercial crop. The main program objectives remain the improvement of yield and adaptation, development of the grain endosperm (plumpness and test weight), further development of disease resistance, and broadening of the germ plasm base.

An expanded research effort to produce octoploid (bread wheat x rye) triticales will occur during the 1980s, although the existing work on hexaploids (durum x rye) will also continue. The octoploid form of triticale may lead to improved seed type and baking qualities, a more semidwarf plant habit, and greater earliness.

Yield and adaptation

In 1979, international testing data continued to confirm the high-yield potential of triticale, with an up to a 100 per cent production advantage over wheat in areas of acidic soils and cool highland production environments. In addition to its direct food value, triticale is also an excellent feed grain and forage crop.

Seed type and test weight

The normal tendency among triticales is to produce fairly good grain test weights (function of grain plumpness) under the best growing conditions, but under some conditions the grain test weights drop sharply. Progress in improving triticale test weights has been slow. The first real improvement came in 1971 with the line Camel, which began the trend toward higher test weights. Further crosses involving Camel produced the line Panda in 1976, with an even higher test weight, more comparable to the test weights of good bread wheat varieties. Both the Camel and Panda lines have been used extensively in subsequent crosses in an attempt to combine higher test weight with high yield potential and good agronomic characteristics. An increasing number of lines are now emerging from this effort, combining the desired selection criteria.

Disease resistance

Triticales to date have shown a high resistance to rusts and to powdery mildew. International data also show that triticales have excellent resistance to smuts in general. Good resistance to *Septoria tritici* is available in triticale germ plasm, while the resistance to *Septoria nodorum* appears to be poorer. *Ergot* problems have been essentially eliminated in the new triticale lines. Barley yellow dwarf virus (BYDV), to date, has been the major virus disease of triticale. Here again, sources of tolerance (Beagle line and its derivatives) appear to exist to this virus disease and will be used to broaden the resistance of triticales to BYDV.

Widening of triticale germ plasm

To introduce fertility, all strains of triticale developed in Mexico were crossed with the line Armadillo. This resulted in a temporary narrowing of the germ plasm base with accompanying disadvantages. CIMMYT breeders continue to broaden the genetic base of new triticale lines using three primary methods:

(1) inter-crossing triticale with bread wheat, durum, and rye species;
(2) creation of new primary triticales (durum x rye; bread wheat x rye); and
(3) crosses of the Mexican spring triticales with winter germ plasm from Europe and North America.

Triticale is showing a clear productive advantage over other small cereal grains in cool highland production environments, such as here in the Himalayas.

International testing

In 1979, the requests for triticale nursery sets continued to grow, increasing 40 per cent over the previous year. In total, 559 individual nursery sets were distributed for worldwide testing. Eight different international nurseries were prepared in 1979 for distribution to national collaborators:

Nursery	Lines	Sets
F_2 – Irrigated	309	56
F_2 – Dryland	311	56
F_2 – Spring x Winter	103	75
CB – Crossing Block	430	45
ITSN – International Triticale Screening Nursery	328	179
ITYN – International Triticale Yield Nursery	25	101
TDRN – Triticale Disease Resistance Nursery	86	26
Forage lines	101	21

New varietal releases in 1979

During 1979, 13 cultivars were released for commercial production by national collaborators. All these new varieties were derived from CIMMYT lines. Countries and the number of varieties were:

Australia (4)
Canada (2)
Hungary (1)
Italy (1)
Mexico (2)
Spain (1)
USA (2)

BARLEY

Barley is one of the most dependable cereal crops where drought, short growing seasons and alkaline or saline soils are encountered. It is used as a human food, a livestock feed, and for barley malt. A substantial number of people depend on this cereal crop in the Mediterranean region, the Mideast, India, China, Korea and the Andean region.

Although improved varieties have been developed for livestock feed and barley malt, most barley eaten by humans has been low yielding and susceptible to diseases. Moreover, the tough hulls around the barley grain, while useful in livestock varieties, must be removed before the grain is eaten by humans. The removal of this hull is laborious and reduces protein levels.

In 1972, CIMMYT began to improve barley for use as a human food. Since that time, many thousands of improved lines have been developed and distributed to collaborators around the world. CIMMYT breeding is focused on developing high-yielding, widely adapted varieties that are resistant to diseases and lodging and have good nutritional quality. The program also seeks to develop good hull-less types as well as earlier maturing lines. This program is conducted in collaboration with ICARDA.

Yield potential and adaptation

CIMMYT advanced lines have continued to improve in their yielding ability and their breadth of adaptation. Eleven advanced lines included in the Fifth International Barley Observation Trial (IBON), 1978, had average yields across all locations ranging from 4.7 to 5.7 t/ha. In the 1978–79 yield trials at Ciudad Obregon, 30 advanced lines had yields in the 5.5 to 6.6 t/ha range.

Disease resistance

In CIMMYT's early barley improvement work, the breeding emphasis was on improving the general barley plant type. Current materials now have greatly improved straw strength, earliness, semidwarf habit and are high yielding across environments. Now that these improvements are well under way, a shift is being made in the program to concentrate more on barley disease problems, which can be particularly serious in Latin America and East and West Africa. The three most devastating barley diseases are rhyncosporium, stripe rust and barley yellow dwarf virus. In recent years, CIMMYT's germ plasm has been enhanced by the incorporation of new lines from Ethiopia with resistance to these diseases. In the breeding scheme followed by CIMMYT, special crosses are being made in Mexico for subsequent screening in disease "hot spot" areas. National program personnel in the Andean region and East Africa are cooperating with these special screenings.

Nutritional quality

After an extensive search during the last several years, CIMMYT scientists have assembled 50 improved lines carrying genes for considerably higher total protein and better protein quality (high lysine). These lines are grouped into a special crossing block. In general, they are acceptable agronomic types, although they still need further improvement and better disease resistance. These high-protein quality lines are distributed to cooperators worldwide through the IBON nursery.

Earliness

The efforts to reduce the growing cycle of the barley crop without a substantial reduction in yield are showing good results. CIMMYT scientists have developed barley lines

Current CIMMYT barley materials have improved plant type, improved straw strength and earliness coupled with high-yielding ability.

that yield in the 3.5 to 4.5 t/ha range and which reach harvest time 30 to 40 days earlier than most traditional varieties. These early barleys may prove valuable for farmers located in low-moisture or short-season environments by giving them a more dependable crop. More extensive multilocational testing with national collaborators is now under way.

Hull-less grain

Approximately 30 per cent of the CIMMYT lines undergoing improvement carry the hull-less character. Some lines have been developed which can compete in yields with some of the better standard commercial hulled varieties. However, these hull-less lines often suffer considerable seed damage during threshing, which results in reduced germination; the more exposed embryos suffer the greatest seed damage. Indirect measures of selection have been followed to overcome this problem, in that all lines with a low germination percentage are automatically discarded. A search is also being made to find germ plasm with less exposed embryos. About 50 sources have been identified with resistance to this damage.

Spring x winter crosses

The need for winter hardiness in barleys for certain developing countries led CIMMYT to begin a spring x winter crossing program in 1976–77. In 1978–79, 56 sets of spring x winter crosses were distributed to cooperators for evaluation in Turkey, Korea and China.

International nurseries

The number of requests in 1979–80 for international barley nurseries increased 36 per cent over the previous year. Five different nurseries were prepared for distribution in 1979 to national collaborators:

Nursery	Lines	Sets
F_2 – Spring x Spring	426	58
F_2 – Spring x Winter	244	56
CB – Crossing Block	430	35
IBON – International Barley Observation Nursery	291	117
IBYT – International Barley Yield Nursery	25	58
Miscellaneous	625	15

New releases

No commercial releases of barley varieties derived from the CIMMYT program were reported by collaborators in 1979. However, reports from three countries indicated that plans are in the final pre-release stage. These countries and the number of varieties are as follows:

Korea	(1)	Iraq	(1)
Bangladesh	(2)		

SPECIAL GERM PLASM DEVELOPMENT

In the conventional breeding programs, experimental lines are evaluated simultaneously for many desirable traits. Lines which carry a particular character useful to the breeder, but intermixed with large numbers of undersirable ones, are usually rejected in the conventional program. In order to capitalize on potentially valuable germ plasm, a special unit at CIMMYT attempts to transfer useful genes into a line with good agronomic background. The resulting lines are then reintroduced as parents within the conventional breeding program.

Efforts to develop new germ plasm for use as parents in crosses are described below.

Protein improvement

The percentage of protein in wheat flour ordinarily falls in the range of 10 to 12, reasonably good among cereals. Nevertheless, efforts continued in 1979 to develop bread wheat lines with higher levels of total protein and higher protein quality. The wheats with higher protein content used in this crossing program are tall, low yielding, late maturing and susceptible to many diseases. CIMMYT breeders have been able to transfer genes for higher protein into a few high-yielding semidwarf lines with moderate resistance to rusts. At the same time, scientists are looking for additional genes which confer higher protein content; the purpose is to intercross these high protein lines in hopes of pyramiding the genes which control this feature.

Lines emanating from this work were included in yield trials at Ciudad Obregon in 1978–79. A number of lines with superior protein levels yielded 4 to 5 t/ha.

Rust resistance

Work continued in 1979 to identify, transfer and pyramid genes capable of conferring greater and more stable rust resistance to bread wheat. This widening of the genetic base for rust resistance often brings accompanying adverse effects in the yielding ability of these progenies. The second phase of this crossing program, thus, is to cross lines with high rust resistance with high-yielding varieties in hopes of combining these different traits into the progenies.

In another project, dominant genes for leaf rust resistance normally present in tall, late-maturing varieties are being transferred into semidwarf, early-maturing varieties.

More spikelets per head, more grains per spikelet

The number of grains per spikelet and spikelets per head are not the only factors determining grain yields. However, the genetic yield potential of wheat might be pushed even higher if a longer, more grain-filled head could be developed atop ordinarily high-yielding, widely adapted varieties.

CIMMYT scientists have been able to develop experimental lines with 8 grains per spikelet (3 to 5 are the normal number in most bread wheats). Grain filling (plumpness)

In addition to the efforts to increase the yielding ability of bread wheat through spring x winter crosses, CIMMYT is continuing its efforts to increase the head size and spiklet fertility without a reduction in tillering ability in bread wheats.

is the principal problem in these crosses, and added emphasis is being given to improve this character. Earlier-maturing lines with these larger number of grains per spikelet have also been developed. Several lines were selected in 1979 which combine good kernel type and high-yield potential. These will be used in future crosses.

Another cross, containing the winter wheat Tetrastichón in its pedigree, has a head twice as long as most spring wheats. These larger heads have been accompanied by a lower tillering ability (normally, as the number of grains per head increases, the number of tillers per plant decreases). Significant progress has been achieved in improving the tradeoff between large heads and tillering ability, although some problems still exist with grain plumpness in these experimental lines. CIMMYT sees the potential to push maximum yield potential of wheats higher in the newer lines coming out of this project.

Aluminum tolerance

This unit continued work in 1979 on the improvement of aluminum-tolerant Brazilian wheats. As reported under the bread wheat section, a number of higher-yielding, short-strawed, aluminum-resistant lines have been developed in cooperation with Brazilian collaborators. Recent screening nurseries grown in Mexico have also contained some lines with good resistance to *Septoria.*

Additional emphasis is being placed on increasing the head size and fertility of Brazilian wheats. The best Brazilian aluminum-tolerant, short-strawed lines are being crossed with parents with large, fertile heads. Progeny combining these two characters have been obtained.

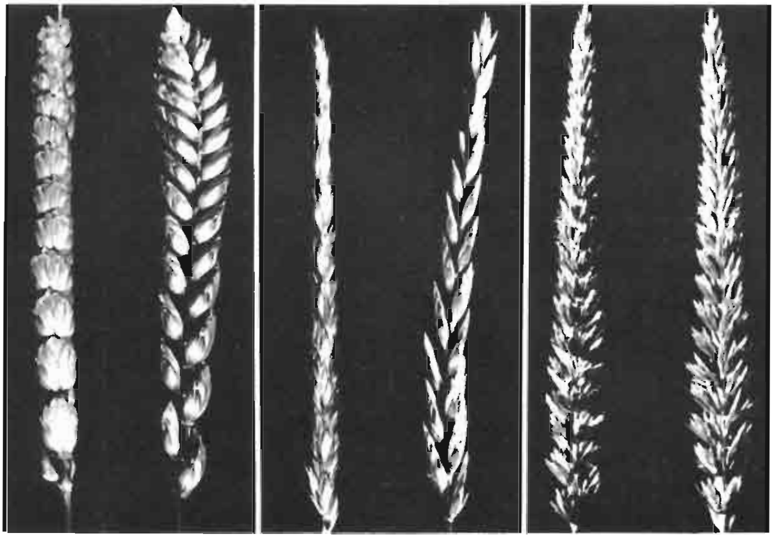
Triticale x wheat crosses

Crosses between triticale and wheat have been under way at CIMMYT for several years. The objective is to stabilize dwarfism in triticales and improve their seed type through the transfer of genes for these traits from bread wheat germ plasm.

In addition, genes carried in triticale for head length and disease resistance may be transferred to bread wheat to improve this germ plasm further.

Wide crosses

In 1979, this unit continued its work on wide crosses,



CIMMYT is placing greater emphasis on wide cross research. Pictured above is a hybrid (center) produced at CIMMYT by crossing wheat (left) and *Elymus* (right), a wild grass species. CIMMYT's aim is to transfer genes into or among its four small grain crops for greater disease resistance, tolerance to environmental extremes and higher protein quality.

working mainly on wheat x barley crosses and to a lesser extent on wheat x *Elymus* and wheat x *Agropyson* crosses. The purpose of this research is to transfer genes from other species into wheat for greater protein quality, disease resistance and tolerance to agroclimatic stresses. Several intergeneric hybrids were obtained in 1979 from these crosses. These hybrids are now being studied by a cytologist, who recently joined the CIMMYT staff, to determine the fate of chromosomes conferred from the different parental species. CIMMYT anticipates that increased research in this area will lead to valuable advances in all four small grain cereals.

AGRONOMY

CIMMYT has long advocated the importance of agronomy research, to improve the productivity of small grain farming. CIMMYT's regional staff are the most heavily involved in production-oriented agronomy research, which is carried out by national collaborators under local conditions. CIMMYT in 1980s will place its major program growth emphasis in the field of agronomy. The staff will work with collaborating national programs to strengthen their agronomic research activities through mounting interdisciplinary research programs capable of reducing the gap between experiment station and farm-level yields. CIMMYT will assist national programs mainly in the design of research procedures capable of generating more appropriate and effect production recommendations for farmers. These activities will be covered under the sections on cooperative programs outside Mexico.

The basic aims of the Mexico-based agronomy program are to provide training for CIMMYT scientists who will later go to regional programs and for the young scientists who come to CIMMYT to participate in the in-service production training courses—as well as to look after the agronomy on CIMMYT's experiment stations. Trials are designed to demonstrate important agronomic principles, giving emphasis to those problems which are encountered in many parts of the wheat-producing world. Treatments are also included in many trials to answer specific questions associated with the management of breeding nurseries on stations where CIMMYT scientists conduct their work.

Weed control

A variety of chemical control agents was tested for effectiveness (and possible side effects) in controlling the major weeds affecting nursery plantings at the different locations used by CIMMYT for small grains breeding and improvement activities.

Nutrient studies

During 1979, this section conducted routine NPK studies, variety-nitrogen interaction experiments, nitrogen fertilizer timing trials and soil amelioration and micronutrient trials.

A particularily interesting finding in the variety x fertilizer interaction trial was that high-yielding semidwarf varieties nearly always outperform traditional tall varieties under low fertility conditions while giving much greater yield response under high fertility conditions.

Variety and advanced line trials

These trials were laid out in farmers' fields, in cooperation with Mexican collaborators, to compare potential new candidates for varietal release in Mexico, using large plot conditions and prevailing farmer management practices.

PATHOLOGY

There are about 40 species of fungi, bacteria and viruses that are parasitic to wheat, barley and triticale. These pathogens are responsible for the diseases which cause the major

The work of CIMMYT pathologists is central to the Center's research efforts to develop disease-resistant varieties which offer greater yield dependability to the farmer.

reductions in yields among the small grains. CIMMYT germ plasm, through the system of international nurseries, is exposed to a large number of pathogens responsible for small grains diseases. By repeatedly testing the materials contained in these nurseries for disease reaction in a wide number of locations around the world, CIMMYT breeders and pathologists are able to identify and develop wheat, barley and triticale genotypes possessing a wide spectrum of resistance.

Among the most serious diseases of wheat and other small grains are the rusts—stem, leaf and stripe. The constant mutation of rust-causing pathogens provides a continuous threat to wheat varieties, including varieties previously considered resistant.

CIMMYT wheat pathologists provide support information to the wheat, barley and triticale breeders. The pathology group is responsible for artificially inoculating nurseries grown in Mexico to impart heavy disease pressure for selection of resistant lines. In turn, these resistant lines are crossed to agronomically desirable types with good yield potential, and the resulting progeny is distributed to breeding programs around the world through the international screening nurseries.

Pathologists also evaluate CIMMYT materials, and those submitted by national collaborators, at six sites in Mexico in uniform nursery trials. In general, the leaf rust levels in Mexico are adequate for good selection pressure, and the risks of "escape" (susceptible materials being selected) are minimal. For stem rust, the infection level in Mexico was not sufficiently severe in 1979 for good selection pressure. Screening for diseases that either are not present or not sufficiently severe in Mexico must take place in "hot spot" areas where they naturally occur. CIMMYT regional programs provide this important function. For example, East Africa is a good area to select for stem rust (also for stripe and leaf rust); the Andean region has good locations to select for stripe rust; North Africa for leaf rust and *Septoria*; and South America for barley yellow dwarf virus. For these and other important diseases, CIMMYT seeks research collaboration with scientists located in the appropriate geographic areas to improve the resistance of CIMMYT materials distributed worldwide.

Pathologists assigned to regional programs are also actively involved in disease surveillance and disease screening of experimental lines through regional nurseries operated in Asia, Africa and Latin America (described later).

Greenhouse studies

Wheat pathologists continued greenhouse work in 1979 to monitor changes in different virulent types of leaf and stem rust. The objective of this program is to continuously monitor the races of rust for possible mutations which would lead to new disease outbreaks to which CIMMYT lines might be susceptible.

Training activities

This group also is responsible for pathology training for in-service training participants. In 1979, five national program pathologists from as many countries completed a seven-month training course in Mexico on pathology research techniques. In addition, several regional workshops on field pathology research techniques were conducted in several regions.

INTERNATIONAL TESTING

In 1979, collaborating scientists in 115 nations requested nearly 2,300 trials of wheat, triticale and barley from 38 different nurseries offered in the wheat program. Each nursery consists of a set of varieties, populations or lines—sometimes as many as 500 entries—which are constituted to serve particular production environments, breeding requirements of collaborators and disease problems.

Collaborators are free to use any of the materials included in a nursery. When its material is directly released as a commercial variety, CIMMYT requests that the origin of the germ plasm be recognized. Further, varieties originating from the international nurseries cannot be protected by patents or plant breeders' rights.

Consulting services to national programs

Wheat pathologists also provide consulting services to national programs. In 1979, CIMMYT pathologists visited a number of disease observation nurseries planted by national program personnel, working hand-in-hand with cooperators in evaluating the disease resistance of experimental lines.

The two largest categories for wheat, barley and triticale are the screening and yield nurseries.

Screening nurseries

These nurseries involve many advanced lines which are grown in double rows for observation and evaluation.

The objectives of screening nurseries are:

(1) To provide cooperating scientists with an opportunity to assess the performance of new advanced lines originating from wheat, triticale and barley breeding programs.
(2) To supply cooperators and CIMMYT 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.

Yield nurseries

Yield nurseries differ from screening nurseries in that the material tested is grown in replicated yield trials. The objectives of yield 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 new sources of genetic variability which may be used directly or as parents for new crosses.

Bread wheat, durum, triticale and barley nurseries distributed in the international nurseries program 1979.

	Bread wheat	Durum	Triti-cale	Barley
Latin America	**231**	**67**	**138**	**76**
Argentina	35	16	6	2
Bolivia	9	10	10	7
Brazil	32	5	22	3
Chile	26	8	15	8
Colombia	8	–	3	3
Costa Rica	5	–	3	1
Cuba	3	–	1	1
Dominican Republic	6	–	3	–
Ecuador	17	4	13	8
El Salvador	2	–	–	–
Guatemala	8	–	6	–
Guyana	2	2	5	–
Haiti	3	–	1	–
Honduras	4	–	2	–
Jamaica	2	–	1	–
Mexico	36	13	25	20
Nicaragua	1	–	–	–
Paraguay	8	–	4	3
Peru	12	9	14	15
Trinidad	3	–	1	–
Uruguay	4	–	2	2
Venezuela	5	–	1	3
Africa	**215**	**95**	**110**	**70**
Algeria	17	15	8	6
Angola	4	–	1	–
Botswana	1	–	1	–
Burundi	3	–	3	–
Cameroon	2	1	1	1
Centr. Afr. Rep.	1	–	1	–
Chad	2	3	2	–
Egypt	17	10	10	7
Ethiopia	13	11	4	3
Ghana	1	1	1	1
Guinea	2	–	–	–
Kenya	14	6	8	7
Lesotho	5	–	4	2
Liberia	3	–	1	–
Libya	6	4	1	3
Malagasy	3	–	3	–
Malawi	4	–	2	–
Mali	3	2	1	–
Morocco	9	2	2	4
Mozambique	6	–	2	–
Niger	2	1	–	–
Nigeria	8	6	5	2
Rwanda	6	1	5	1
Senegal	4	1	1	1
Sierra Leone	7	–	3	–
Somalia	4	2	1	2
South Africa	13	10	16	7
Sudan	10	4	3	2
Tanzania	15	1	6	3
Tunisia	11	8	5	7
Uganda	3	–	2	1
Upper Volta	1	1	–	1
Zaire	1	–	1	–
Zambia	10	4	4	5
Zimbabwe	4	1	3	4
Mideast	**110**	**69**	**58**	**56**
Cyprus	5	4	1	3
Iran	10	2	6	3
Iraq	6	5	2	1
Israel	17	7	8	2
Jordan	9	9	2	8
Lebanon	4	5	2	2
Quatar	4	–	1	1
Saudi Arabia	5	2	1	1
Syria	23	17	17	15
Turkey	19	14	13	11
Yemen, North	7	4	5	3
Yemen, South	7	–	–	–

	Bread wheat	Durum	Triti-cale	Barley
East Asia	**166**	**42**	**80**	**67**
Afghanistan	11	2	2	2
Bangladesh	12	2	3	3
Bhutan	3	–	1	4
Burma	2	1	1	1
China	2	3	–	2
India	31	13	20	19
Indonesia	3	–	1	–
Japan	6	–	5	2
Korea, North	3	1	1	1
Korea, South	11	2	7	6
Laos	1	1	1	1
Mongolia	4	1	1	3
Nepal	14	2	8	6
Pakistan	36	13	16	11
Philippines	11	–	6	–
Sri Lanka	3	–	1	1
Taiwan	1	–	1	–
Thailand	9	1	4	4
Vietnam	3	–	1	1
Oceania	**27**	**9**	**22**	**2**
Australia	13	5	12	1
New Caledonia	5	2	5	–
New Guinea	3	–	1	–
New Zealand	6	2	4	1
Europe	**138**	**88**	**114**	**53**
Albania	4	3	2	–
Austria	–	6	1	–
Belgium	2	6	5	1
Czechoslovakia	4	–	–	–
Finland	3	–	–	2
France	11	10	10	7
Germany,F.Rep.	5	2	7	7
Greece	7	6	6	4
Hungary	5	1	5	–
Ireland	9	–	5	2
Italy	10	14	13	7
Malta	–	3	–	4
Netherlands	3	2	3	1
Norway	4	–	3	1
Poland	5	2	11	2
Portugal	6	2	6	1
Rumania	9	4	7	3
Spain	33	17	11	7
Sweden	5	1	4	3
Switzerland	–	–	3	–
United Kingdom	3	–	6	–
USSR	2	2	1	–
Yugoslavia	8	7	3	2
North America	**72**	**21**	**49**	**31**
Canada	17	5	15	14
USA	55	16	34	17
TOTALS:				
Countries	**113**	**69**	**98**	**67**
Locations	**959**	**391**	**571**	**355**

MILLING AND BAKING LABORATORY

The Milling and Baking Laboratory evaluates the grain of bread wheat, durum wheat and triticale lines for the suitability in making bread, tortillas, chapatis, cookies, spaghetti and other products.

In 1979, the laboratory tested 17,041 samples from early-generation bread wheat lines (F_3 and F_4) for gluten strength. The lines tested represent 42 per cent of a total of 40,556 individual plants selected in the field for good agronomic characteristics; others were discarded for seed type. By screening early generations for seed type, advanced materials have been increased in test weight (weight of grain per unit volume), and due to this type of screening few advanced lines are now discarded because of low grain test weights.

About 1,500 advanced lines and varieties of bread wheat were evaluated in 1979 for milling and baking qualities. A number of lines with good baking and cookie quality were selected from this material. Several lines from the special protein improvement project had protein levels up to 16.2 per cent in flour plus good baking quality.

Each year, CIMMYT cereal technologists evaluate the grain of thousands of bread wheat, durum, and triticale lines for their suitability in making bread, pasta and other products. Each line which comes to be included in screening and yield nurseries has been assessed for grain quality.

In durum wheat the laboratory screened 5,700 individual plants for pigment content, and 320 advanced durum lines were evaluated for spaghetti-making quality. Several advanced durum lines were found with good spaghetti cooking quality. In triticale, 300 lines that had good yield and test weight and 166 lines from the crossing block were evaluated for milling and baking and for quality in cookie-making. In the high-yielding triticale material, almost all the lines tested had a flour yield higher than 60 per cent, with some higher than 70 (good bread wheats have flour yields of 70 per cent). Many triticale lines provide flour that is better for cookies than the soft bread wheats normally used for making these products. (Some triticales also are good for making bread.)

Two trainees from Peru and Turkey spent an average of 3 months each in 1979 learning techniques in the Milling and Baking Laboratory. The laboratory also received a visiting scientist from Pakistan.

Experiments were conducted with various blends of flours—bread wheat flour with maize, with triticale, with durum wheat and with barley. In general, blends of 15 to 20 per cent of the alternate with wheat flour produced satisfactory products. It is believed that this method of extending imported bread wheat flour could be used in countries where alternate crops are grown.

WHEAT TRAINING

The 1979 wheat in-service training program added a new irrigated agronomy course in the Yaqui Valley, Sonora, Mexico.

The course parallels the winter breeding cycle in Ciudad Obregon, beginning in November and ending in May of the following year. In total CIMMYT now offers seven in-service training programs of use to agricultural scientists engaged in wheat-related research and production activities. These are:

(1) Rainfed Wheat Agronomy
(2) Irrigated Wheat Agronomy
(3) Trainers Course in Production Agronomy
(4) Wheat Breeding
(5) Wheat Pathology
(6) Cereal Technology
(7) Experiment Station Management

Most trainees spend one crop season in Mexico. The largest number take part in the production agronomy courses, which stress on-farm research. In addition to planning and managing sets of on-farm experiments during their stay in Mexico, these trainees help evolve strategies for the organization of production research systems. Components of such systems include ways to develop short-term strategies for raising national production and reducing the gap between the yields obtained from on-station research and those

Origin of Wheat in-service trainees, 1966-79.

	1966-1979	1979*
Latin America	**151**	**17**
Argentina	14	2
Bolivia	13	3
Brazil	18	1
Chile	8	1
Colombia	5	0
Dominican Republic	1	0
Ecuador	16	3
Guatemala	8	1
Guyana	1	1
Honduras	1	0
Mexico	44	2
Panama	1	0
Paraguay	5	1
Peru	15	2
Uruguay	1	0
North Africa and Mideast	**181**	**7**
Algeria	49	4
Cyprus	1	0
Egypt	12	0
Iran	8	0
Iraq	5	0
Jordan	5	0
Lebanon	4	0
Lesotho	1	1
Libya	4	0
Morocco	18	0
Saudi Arabia	1	0
Sudan	3	0
Syria	6	0
Tunisia	24	0
Turkey	37	2
Yemen	3	0

	1966-1979	1979*
Africa, South of the Sahara	**52**	**4**
Cameroon	1	1
Chad	1	0
Ethiopia	11	0
Kenya	7	0
Malagasy	1	0
Malawi	2	1
Mali	1	0
Nigeria	14	0
Rwanda	2	1
Somalia	1	0
Tanzania	4	1
Zaire	2	0
Zambia	5	0
South, Southeast and East Asia	**113**	**12**
Afghanistan	13	0
Bangladesh	24	4
India	14	2
Korea	1	1
Nepal	12	1
Pakistan	39	3
Philippines	2	1
South Korea	8	0
Other Countries	**19**	**1**
France	1	0
Hungary	2	0
Poland	3	0
Portugal	2	1
Rumania	2	0
Spain	2	0
USA	4	0
USSR	3	0
TOTAL: Countries	**59**	**24**
Individuals	**516**	**41**

* Does not include trainees from irrigated production training and other in-service courses which began in November 1979 and end in May 1980.

experienced on farmers' fields. Working with the wheat and economics program staff, trainees are developing procedures to identify, survey and process information affecting farming situations, and, through this, to improve the focus of agricultural research.

CIMMYT's wheat breeding and pathology training programs have been modified in recognition that experiment station conditions in national programs are often substantially different than the facilities encountered at CIMMYT. Trainees, therefore, work "off" as well as "on" the stations used by CIMMYT in Mexico. These trainees plant screening trials on farmers' fields in order to test germ plasm developed under "ideal" irrigated experiment station conditions. With this focus, trainees get a more realistic exposure of the management factors involved in conducting breeding and pathology research. Consequently, they come away from their stay in Mexico with greater self-reliance in conducting crop improvement programs.

Visiting scientists

In 1979, CIMMYT brought 24 visiting scientists to its El Batan headquarters and some 20 other collaborating national scientists to the winter station in Ciudad Obregon.

Each year, CIMMYT receives senior visiting scientists from around the world. These scientists come to CIMMYT to exchange information, assess CIMMYT germ plasm and to become familiar with the research procedures used by CIMMYT scientists in their work.

Some visiting scientists are former CIMMYT in-service trainees who return to familiarize themselves with new germ plasm and research developments. Others have long been collaborators in the international nurseries network and come to help select materials of special interest. Other are government policy makers interested in understanding more about the steps involved in crop improvement and production.

Graduate student training and doctoral fellows

During 1978–79, with outside financial sponsorship, CIMMYT is cooperating in the training of nine master's degree candidates (Algeria, Ecuador, Mexico and Peru); and seven postdoctoral fellows (Morocco, Poland, Sierra Leone, Syria, Uganda and USA).

COOPERATIVE PROJECTS OUTSIDE MEXICO

In 1980, CIMMYT will increase the number of wheat scientists posted outside Mexico, shifting more toward regional assignments. Staff posted to national programs in 1979 was reduced with the transfer of two wheat scientists previously posted in Algeria. By year's end, CIMMYT had one scientist (in Pakistan) working directly within a national program. In 1980, a new regional program will begin in North and West Africa, with headquarters in Portugal. In addition, existing regional programs will be strengthened with the assignment of new staff.

Regional programs

At the beginning of 1980 CIMMYT wheat scientists were assigned to the following regions:

Wheat region	Number of cooperating countries	Assigned staff 1979
Disease Surveillance	22	2*
East Africa	17	2*
Andean Region	5	1
Southern Cone	6	2

* Two scientists on loan from the Dutch Government serve as associate CIMMYT staff in the regions noted.

Disease Surveillance regional program

This program is funded by the government of the Netherlands and is operated in cooperation with our sister institute, ICARDA. The problems of wheat diseases continue to be the major activity for the two scientists assigned to the region since 1973. These CIMMYT staff, one posted in Turkey and the other in Egypt, cover a wheat-growing area which stretches from Morocco in the west, through East Africa and to the Indian subcontinent in the east. This area accounts for a considerable amount of the wheat production in the developing world. The major wheat-producing sub-areas (Asia Minor, the greater Punjab of the Indian subcontinent, and Mediterranean North Africa) of this region are vast contiguous expanses of wheat cropland.

In addition to the normal regional program activities, the CIMMYT regional scientists are working on two unique projects: a disease surveillance-early warning system for the region and a series of in-service pathology workshops concentrating on practical field and laboratory methods for screening and identification of resistant lines.

The surveillance program is gathering regional disease information through two widely distributed nurseries: the Regional Disease and Insect Screening Nursery (RDISN) and the Regional Disease Trap Nursery (RDTN).

The RDISN is made up of approximately 2,400 advanced lines of bread wheat, durum wheat, barley and triticale originating from CIMMYT, national breeding programs within the region and ICARDA. The nursery is distributed in cooperation with ICARDA to about 50 locations in over 30 countries.

The RDTN consists primarily of commercial varieties, susceptible check varieties, promising advanced lines with new sources of resistance, and differentials for the three rusts. In addition to providing cooperators with the opportunity of testing their materials in a variety of disease environments, the RDTN acts as a surveillance system for changes in pathogen races throughout the region. The RDTN is sent annually to 150 locations in 50 countries of North Africa, the Mideast and the Indian subcontinent. The Dutch government has provided a grant and technical assistance to develop a computerized analytical package to process the data reported by collaborators growing these regional nurseries.

A cereal disease methodology workshop was held for national pathologists in the region at Aleppo, Syria, in April 1979, in cooperation with the Institute for Plant Protection (IPO) of Wageningen and ICARDA. In this workshop, lectures on theory were followed by practical field and laboratory applications. At the end of the workshop, each participant received a complete set of pathology research and rust spore storage equipment for his institute (courtesy of the Dutch government). A similar workshop was conducted in Chile in December for scientists from all of South America.

In addition to a variety of within-region training activities, 12 national program staff members from the region completed in-service wheat training courses in 1979 at CIMMYT.

Eastern and Southern Africa regional program

This region includes 17 African countries from Ethiopia in the north to Lesotho in the south. Together, these nations produce about 1.5 million tons of wheat, not sufficient to supply the domestic demand for wheat flour. Most of the small grains are grown in this region in highland areas above 1,700 meters altitude, with heavy presence of serious wheat disease problems. Starting in 1976, CIMMYT assigned one wheat breeder to this region with headquarters at the Kenyan National Plant Breeding Station, Njoro, at 2,300 meters elevation. The area around Njoro is characterized by virulent races of the stem rust pathogen; recently, heavy levels of stripe rust have been present. This makes it an excellent area to screen wheats for resistance.

For many years, the Kenya government has assisted other national breeding programs by providing land at the Njoro station for the planting of "off-season" nurseries. CIMMYT assists in this off-season nursery program. Close cooperation is maintained in this work with ICARDA, which serves many of the national programs using the off-season nursery facilities in Kenya.

In 1979, the Dutch government assigned a pathologist to Kenya to collaborate with the CIMMYT regional program as a staff associate. In addition, CIMMYT pathologists assigned to the Mediterranean and Asian regional program spend about a month each year in eastern and southern Africa countries, helping to backstop the pathology work of national collaborators.

Two nurseries are distributed in this regional program:

the African Cooperative Wheat Yield Trial (ACWYT) and the East African Screening Nursery (SNACWYT).

The ACWYT distributed in 1979 included 13 advanced lines and commercial varieties of bread wheat, durum wheat and triticale. The nursery was distributed to 13 locations in the region. Early results from Kenya, Tanzania and Zambia again showed that triticales were significantly higher in yield than the bread wheats. The ACWYT was also sent to 15 countries outside Africa, including Mexico and Ecuador (Andean program), to help introduce sources of resistance to the virulent forms of the rusts found in East Africa and to test this germ plasm in a wider range of conditions and diseases.

The SNACWYT is a screening nursery comprised of advanced lines from East African national programs assembled by the CIMMYT regional staff and colleagues from the Kenya national program. In 1979, the SNACWYT included 111 bread wheats, most with good stem and stripe resistance; 34 durum wheats; 52 triticales; and 11 oats selections. This nursery is distributed to the same collaborators as the ACWYT described above.

Four agricultural officers from national programs within the region completed in-service training programs in Mexico during 1979.

Andean regional program

Beginning in 1976, CIMMYT assigned one wheat scientist to work with the national programs of five countries in the Andean region (Bolivia, Colombia, Ecuador, Peru and Venezuela). These countries imported nearly 2.5 million tons in 1979, producing less than 700,000 tons of wheat and barley, far below the productive potential of the region.

From a strictly breeding standpoint, the virulent forms of stripe rust and barley yellow dwarf virus make the area valuable in global screening efforts for lines with greater resistance to these disease problems. Two regional nurseries are presently distributed by the Andean regional program from its base in highland Ecuador. These are the Latin American Wheat Disease and Observation Nursery (VEOLA) and the Latin American Rust Nursery (ELAR).

The VEOLA consists of approximatley 500 varieties and advanced lines of bread wheat, barley and triticale which originate from national programs in Latin America and CIMMYT. The VEOLA is the western hemisphere equivalent of the RDISN described previously. The nursery is a cooperative activity of CIMMYT and INIAP, Ecuador's national agricultural research institute. In addition to supplying regional disease information, the VEOLA facilitates the exchange of disease-resistant materials. The outstanding lines and varieties grown in the RDISN, SNACWYT and VEOLA are included in the following year in the other regional nurseries, thus adding to the information on regionally superior disease-resistant germ plasm.

The ELAR contains commercial varieties, disease resistant and susceptible advanced lines, germ plasm with new sources of disease resistance, and the differentials for the three rusts. These materials originate from breeding programs throughout the western hemisphere. The objective of ELAR, which is similar to the RDTN, is to survey virulence patterns of wheat pathogens, identify disease "hot spots," identify race origins of pathogens and serve as an early-warning system for new mutations of pathogens.

Eight Andean region wheat scientists completed CIMMYT's in-service training programs in 1979: four in wheat production; two in plant breeding and pathology; one in experiment station management; and one in cereal technology.

Southern Cone regional program

This regional program began in late 1978 and covers areas of five Southern Cone countries of South America (Argentina, Brazil, Chile, Paraguay and Uruguay). In 1979, a two-man regional staff—one agronomist and one breeder—were in place, working out of Chile's national agricultural research institute (INIA) in Santiago, and in cooperation with IICA, the Inter-American Institute of Agricultural Sciences. Much of 1979 was devoted to discussions of regional research problems with national collaborators.

The proposed program in this region has many of the same elements found in other regional programs. The special emphasis in the Southern Cone is being placed on soil-fertilizer problems related to wheat, barley and triticale production. In particular, the problems of aluminum toxicity and phosphorus fixation tendencies are a major focus of the program.

economics program

INTRODUCTION TO ECONOMICS PROGRAM

From its beginning, the economics program has been directed towards new ways in which research on the farmer and his markets could facilitate the development and diffusion of improved agricultural technology. While its objective remains unchanged, the program's activities have evolved during the 1970s, concentrating more on developing analytical tools to help guide the design of agricultural research programs and accenting more collaboration with biological scientists. The activities described below are interrelated but will be singled out for separate comment.

Beginning in 1972, a series of adoption studies examined the characteristics of farms and farmers in less developed countries, analyzing why some farmers adopt new technology and some do not. Seven studies were made, examining farmers who grew maize in Colombia, El Salvador, Kenya and Mexico; and others who grew wheat in India, Tunisia and Turkey. These studies were based on a perception of the farmer as one seeking to increase incomes while tending to avert risks. The primary conclusion was that, while the farmer is influenced by a host of factors in selecting technologies, his primary decision-making determinants are his physical circumstances (rainfall, soil depth, temperatures), his biological circumstances (diseases, insects, other plants and their interactions with crops), and his economic circumstances (the alternative uses of his resources and the markets through which he buys and sells).

The adoption studies demonstrated that economists could play a close collaborative role with biological scientists early in the process of developing new technology. Underlying this collaboration was the idea that as farmers assess alternative technologies, they are heavily influenced by their own natural and economic circumstances; therefore, research aimed at formulating useful technologies must also integrate these phenomena. In 1975, we set out to develop effective procedures for systematically identifying the circumstances of representative farmers and for incorporating this information into action-oriented research programs geared to develop new technologies for adoption in the short and intermediate run. These experiences are being synthesized into a manual which describes these procedures developed in close collaboration with national programs.

In training, cooperating with the maize and wheat programs, economists work to develop in-service trainees' skills in analyzing the factors affecting farmers' decision making.

As part of our contribution to training, we produced a manual to illustrate the formulation of recommendations for farmers. This manual, written for agronomists, illustrates all steps in deriving "economic" recommendations, starting with agronomic data, blending in the relevant economic data, and then developing practical recommendations. First published in 1976, it is now available in English, Spanish, Turkish and Arabic, with the French version to follow in 1980. A second manual, addressing the identification of farmer circumstances and their relevance to planning on-farm experiments, will be released in English and Spanish in 1980.

As interest mounted in the procedures that we were developing, we were encouraged to offer a training program for other economists. In 1979, six economists from developing countries joined us as visiting scientists to acquaint themselves with the ideas that guide collaborative research with biological scientists. Their program contains roughly equal parts of work on crops and on procedures. Starting in 1980, two sessions will be held per year.

Posting regional economists outside Mexico began in 1976, when our small headquarters staff (then two) was unable to cope with the calls for consulting on economic studies within national maize and wheat programs. In 1979, regional economists were serving four regions. Highlights of their activities are included in this report.

Most recently we have turned our attention to policies which influence the development and diffusion of improved technologies and asked: What do policy makers need to know about farms and farmers in order to facilitate the development and use of improved technologies? Responses to this question were drawn from talks with farmers, with scientists, with national agricultural administrators, and with educators. Our findings led to the establishment of management seminars for decision makers. The first seminar was held in The Philippines and three or four are planned for 1980.

D. L. Winkelmann

PROCEDURES

CIMMYT economists concentrated considerable effort in 1979 on the development of inexpensive but effective procedures to obtain information on farmers' circumstances of use to biological scientists in the design of on-farm experiments. A manual addressing these issues will be released in 1980.

The procedures developed by CIMMYT and national collaborators were discussed in an April 1980 Workshop attended by scientists from other international institutes and national programs who are engaged in on-farm research. The CIMMYT-advocated procedures were endorsed as cost-effective for target crops such as maize and wheat.

Work on refinements in these on-farm research procedures will continue in 1980. Of current interest is the development of cost-effective procedures to obtain farmer assessments of new technology, before that technology is widely extended. This farmer assessment provides a final check on the appropriateness of recommended technology within the farming systems of target farmers.

Research procedures also are being developed to analyze relations between farmer circumstances, yield constraints and agricultural policy. This is a relatively new area of research that appears to be very promising.

TRAINING

The economics staff contributes to total center efforts in training in four ways: by participating in the instruction of maize and wheat in-service trainees in Mexico; by helping with training on crop management in the region; by a program of visiting economists and doctoral fellows; and by preparing materials of special interest to agricultural officers.

Maize and wheat in-service production trainees spend roughly one-quarter of their stay in Mexico focusing on the economic aspects of crop production, with particular emphasis given to on-farm research procedures for assessing farmer circumstances. Economists share in planning farmer interviews and on-farm experiments which are carried out by in-service maize trainees in the lowland tropics of the state of Veracruz, Mexico, and by wheat trainees in the rainfed upper plateau of central Mexico. This training stresses the importance which must be given to farmer circumstances and decision making in research to develop improved technologies.

CIMMYT economists are becoming increasingly involved in training activities within the regions where they are assigned. The emphasis of these activities, done in collaboration with biological scientists, is aimed at refining research systems which develop technologies for transfer to local farmers. The in-country training activities in 1979, in which CIMMYT economists participated, are covered under regional program reports.

Beginning in 1979, the economics staff initiated a training program for national program agricultural economists

The economics program added a training course for national economists engaged in on-farm research. The emphasis of this course, held twice each year, is on teaching procedures used in research to generate more appropriate farmer recommendations.

who work as part of maize and wheat production research teams. Two cycles are conducted each year. The first, for agricultural economists concerned with maize production, is held in the first part of each year with field work carried out in the state of Veracruz, alongside maize in-service production trainees. The second course, for agricultural economists working in wheat production research, begins in late April with fieldwork done with wheat in-service production trainees in the upper plateau of Mexico.

The visiting scientists who participated in this program were all from developing countries; they will engage in national production research programs on returning home. While in Mexico, they take part in on-farm experimentation, conduct interviews and surveys with farmers, observe on-farm trials, and attend wide ranging seminars on topics relating to biological and economic aspects which need consideration in the development of improved technologies.

Three doctoral fellows were also working with the economics program in 1979. One, an anthropologist, began work in Ecuador 1978 to assess the need to incorporate information on diets into the design of research on agricultural technologies. Another, a predoctoral fellow working in Mexico, is involved in assessing alternative methodologies for undertaking collaborative research and in the training of maize production specialists. Another predoctoral fellow is working within the East African regional program to train agricultural researchers in the on-farm research methodologies advocated by CIMMYT.

Management seminar for agricultural decision makers

The CIMMYT trustees authorized a three-year project to organize a series of management seminars for agricultural decision-makers from developing countries. These seminars, enlisting the skills of outside specialists, are held on a regional basis and utilize the "case study" teaching method. By presenting several case studies which relate to public policies affecting agriculture, the seminar leaders emphasize the importance of considering farmer circumstances along with biological, economic and political factors when formulating agricultural policies.

The first of these seminars was held in mid-1979 in The Philippines, in association with the Southeast Asian Research

Center for Agriculture (SEARCA). Eighteen participants—from five countries with diverse professional backgrounds and job responsibilities in agricultural development activities—attended the seminar. Each case study presented a specific decision-making situation and included background material and technical notes describing the dimensions in detail. Combining these materials with their own experiences, the participants were asked to formulate operational solutions to the problem posed by the case.

Before transferring this project to another institution, CIMMYT will conduct several more seminars in 1980 in Asia, Latin America and Africa. Because of the experimental nature of the project, several options will be tested in upcoming seminars related to case material, mixture of participants, supplementary lectures, length of seminar and discussion leaders.

COOPERATIVE PROJECTS OUTSIDE MEXICO

CIMMYT's regional economists worked in four regions in 1979. These staff members collaborated with maize and wheat scientists and economists in national programs where they encouraged interdisciplinary research—involving biological scientists and economists—aimed at the development of technologies useful to representative farmers. This involved bringing local economists together with biological scientists; consulting on the organization of micro-level research; providing financial support for such work where necessary; and cooperating in drawing out the agricultural policy implications which emerge from the work.

In addition to the regionally assigned staff, one economist began working in 1979 with scientists in the Algerian national research program on a special project aimed at relating the limitations on yields, evidenced in on-farm trials, to farmer perceptions of natural and economic circumstances, and then to the policy dimensions which shape farmer decision making.

East African regional program

The regional economist, supported by funds from UNDP, is working mainly with the national research programs in Kenya, Tanzania, Malawi and Zambia. Beginning in 1979, he has had the assistance of a predoctoral fellow who is working with a Kenya training program for farm economists engaged with crop scientists in on-farm research.

In two national programs—Kenya and Zambia—a strong commitment has been made to the on-farm research methodology advocated by CIMMYT; Zambia is developing a nationwide adaptive research team, and both countries are developing the operational procedures and the capacity to conduct such programs.

In Kenya, 15 farm economics trainees have been assigned to various stations throughout the country to work within production research teams, focusing their work on surveys to orient on-farm research experiments. Four training workshops were held in Kenya in 1979, covering on-farm survey techniques and their use in design of farm-level experiments. CIMMYT assisted in teaching these workshops, which were also attended by farm economics trainees from Zambia.

In 1980, a training workshop in on-farm research procedures is planned in Zambia. In addition, a Management Seminar for Policy Makers will be held in Kenya in May 1980, with participants drawn from various East African countries. Finally, a concepts and strategies evaluation workshop, related to developing national on-farm research programs, will be held in early 1980 for scientists from the region.

South Asian regional program

A regional economist, supported by UNDP funding, has been posted to this program since 1978 with the responsibility of working with scientists from national programs (Bangladesh, India and Nepal) in on-farm research. The emphasis of the work related to small grains production is on developing and introducing triticale for the Himalayan hills. These hills, stretching from Afghanistan to Nepal, are populated by small farmers and dominated by production environments where triticale seems to offer marked advantages over wheat. This work was the subject of a regional triticale workshop held in April 1979.

The CIMMYT regional economist and maize breeder/agronomist also were involved in on-farm projects in two Indian states (Uttar Pradesh and Bihar) aimed at improving maize technology. Both are being conducted by local researchers.

Several agricultural economists from this region also participated in the visiting scientist training program in Mexico in 1979.

Andean regional program

An economist was posted to the Andean region in late 1977 for cooperative research work in Colombia, Ecuador, Peru and Bolivia. This work has concentrated on floury maize, a dominant crop in the highlands; on wheat and barley, secondary crops in highland farming systems; and on tropical maize in the costal regions.

Within the region, two countries—Ecuador and Peru—have made a strong national commitment to on-farm research. CIMMYT economists support these efforts through co-operative work to develop and refine research procedures and through training assistance.

In 1979, two training courses were offered in Ecuador in on-farm research procedures for maize workers. These training programs involve three or four "calls" each year in which trainees are convened at key stages in the crop cycle. For example, trainees were called together at planting, flowering and harvest time for specific training segments, each lasting from one to two weeks. CIMMYT economists and maize staff members assisted in these workshops. Similar training programs are planned in 1980 for wheat scientists in Bolivia and maize workers in Peru.

Central American regional program

The regional economist, assigned in 1978 to this region and supported by Swiss funding, has concentrated his efforts in Panama and El Salvador, where he is working with national collaborators in on-farm research activities. Both these Central American countries have made a strong commitment to nationwide on-farm research programs. In Panama, the national agricultural research institute (INDIAP), began its on-farm research in one area (CAISAN) in 1978, concentrating on the maize crop and associated rotations. CIMMYT collaborated with this project, particularly in the farmer interview and survey phases. Next, on-farm experiments were planned and initiated. The information gleaned from this area-specific project led INDIAP to expand its on-farm research activities to other areas of the country. By early 1980, farm surveys—

informal and formal—will have been completed for 16 production areas. CIMMYT continues to work with national scientists in this program.

In El Salvador, on-farm research activities also have expanded nationwide. A full-time team formed by 14 extensionists and eight researchers, representing different disciplines, was assigned responsibility for this program. The first step—farmer surveys—has been largely carried out, and CIMMYT has assisted in the development of analytical procedures to process the ensuing data.

The regional economist has also assisted the regional maize program staff in Honduras and Costa Rica, where on-farm research projects are under way. Honduras and Haiti will receive more emphasis in the future. Various training-related activities also were carried out in 1979 in several countries of the region.

supporting services

EXPERIMENT STATIONS

CIMMYT conducted research at seven stations in Mexico during 1979. 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*) 17 (maize)	Nov-May Jun-Dec
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) 26 (wheat*) 4 (sorghum***)	Apr-Dec May-Nov Apr-Oct
Toluca–CIMMYT	2,640	19	43 (wheat*) 5 (wheat*) 15 (maize) 3 (potatoes***)	May-Nov Dec-May Apr-Dec Mar-Nov
Poza Rica–CIMMYT	60	20	41 (maize 4 sorghum***) 1 (wheat)	Dec-May First cycle Jun-Nov Second cycle Nov-May
Tlaltizapan–CIMMYT	940	18	31 (maize) 1 (sorghum***)	Dec-May First cycle Jun-Dec Second cycle

* Includes barley and triticale
** CIMMYT nurseries planted for observation on diseases
*** Potatoes in cooperation with CIP; sorghum in cooperation with ICRISAT

El Batan

Final regulation of the drainage outlet for the El Batan station was completed prior to the start of the 1980 crop season. Problems of root rots have necessitated application of 1 t/ha of sulfur to all wheat fields during the winter fallow.

All fields have been cover-cropped with vetch (*Vicia* spp.) during the winter fallow. Garden pea (*Pisum* spp.) has been used in two fields to permit observation of its effect on the reduction of take-all root rot (*Ophiobolus graminis*). Vetch has continued to show good tolerance of atrazine residue in maize blocks.

Heavy frost damage that occurred in September led to some losses in the breeding nurseries.

Toluca

The new drainage outlet scheme has been completed and has resulted in better use of fields at the lower end of the station. The average water table level is dropping due to increased industrial and domestic use in the watershed area around the station. This has led to a closer look at the efficiency of use of irrigation water.

Vetch and garden pea are being used to cover all fields during the winter fallow. Frost damage in September was especially severe in maize and triticale.

Poza Rica

Soil variability brought about by annual flooding from the San Marcos River continued to influence the results of trials in some fields. A by-pass channel for the river was completed in July and proved helpful during the September flood.

Herbicide and fertilizer trials were initiated with the objectives of obtaining better weed control, leaving less herbicide residues in the soil, and permitting more effective use of water and fertilizers. In trials completed in 1979, the "alternate furrow" irrigation method proved superior to the "every furrow" method in terms of weed control and maize yields.

The search continued for legumes tolerant to atrazine residues—for cover-cropping fallowed fields. *Canavalia brasiliens* in summer and *Vicia* spp. in winter showed some promise.

Tlaltizapan

Soil incorporation of bagasse continued to alleviate the micronutrient deficiency brought about by high calcium levels in the soil, which is derived from limestone. Chlorosis in maize plants is now considerably reduced and can be seen in only a few genetic materials when they are grown in areas where the soil parent material is shallow.

Training

Two full training courses in experiment station management were given during 1979. The first was held from March to July 1979, and the second, from September to January 1979.

Nine persons from as many developing countries participated in these courses. In October 1979, the training base was changed from El Batan to CIANO, Ciudad Obregon, Sonora. Several scientists and other visitors interested in station management were also accommodated.

Visits and Consulting

The Head of Experiment Stations and the Training Officer spent 11 weeks consulting on problems of experiment station development and management in seven countries.

LABORATORY SERVICES

The Protein Quality Laboratory and the Plant Nutrition and Soils Laboratory continued to provide analyses to all the CIMMYT crop programs in 1979. The activities of these laboratories are described below. (The Milling and Baking Laboratory is described under the wheat program, page 71.)

Protein Quality Laboratory

During 1979, the protein laboratory analyzed approximately 19,500 maize samples, of which 14,000 were maize endosperm samples, for protein and tryptophan. (Measuring tryptophan gives an indirect but rather precise indication of the level of lysine, the determination of which is more laborious and expensive.)

Approximately 5,600 maize whole-kernel samples of more advanced materials were evaluated in 1979 for their protein quality index.

The variability in oil content was studied in one maize population to determine how much the oil content of maize can be increased.

Analyses for protein content and for protein quality also were performed on approximately 900 barley, 1,000 triticale and 1,000 wheat samples. Complete amino acid analyses were performed on approximately 75 selected samples from the various programs, and 8 samples were tested in animal-feeding trials.

Laboratory training

CIMMYT staff have provided assistance to several countries in establishing their own quality laboratories to give service to national breeding programs. In addition, the laboratory staff also assist in training personnel from national programs in chemical protein evaluation. In 1979, six trainees—Pakistan (2), Bolivia (1), El Salvador (1), Poland (1) and Turkey (1)—spent different periods of time in Mexico.

Plant Nutrition and Soils Laboratory

During 1979, 1,150 soil samples were evaluated to provide information about fertility conditions and soil management practices at CIMMYT experiment stations. Some soil analyses were also conducted for the production training programs relating to on-farm experiments.

CIMMYT experiment stations requested that 79 water samples be analyzed for irrigation quality characters.

The laboratory also analyzed 409 samples of vegetal tissue to determine some yield-limiting factors under optimum agronomic conditions in relation to photosynthetic efficiency, light competition and plant height. In addition, 343 samples of vegetal tissue (leaves, stems and grain) were analyzed for nutrient uptake, translocation and storage under different fertilization treatments.

INFORMATION SERVICES

Thirty-one new publication titles were released during 1979. The serial, CIMMYT TODAY, was continued with two new issues in 1979. In addition, a number of national collaborators (with our encouragement) translated CIMMYT publications into local languages, printing and issuing them under national imprimaturs; CIMMYT's publications staff assisted in these efforts.

The Commonwealth Agricultural Bureau (United Kingdom) issued on behalf of CIMMYT Volume 5 of the Maize Quality Protein Abstracts (MQPA) and Volume 5 of the Triticale Abstracts (TA). About 650 maize scientists receive MQPA, and about 400 scientists receive TA.

Mailing lists

About 4,500 names were included on CIMMYT mailing lists in 1979. These listings are classified accordingly: 24 per cent wheat specialists, 22 per cent maize specialists, 43 per cent general agriculturalists, 11 per cent libraries; by language, 62 per cent English and 38 per cent Spanish; by geographic areas, 10 per cent Europe, 21 per cent North America, 38 per cent Latin America, 11 per cent Africa, and 20 per cent Asia and the Pacific.

Audio visuals

The video taping unit produced 36 video tapes in 1979 for the training programs and visitors service unit. A slide filing/retrieval system was installed. The graphic arts department and photography unit continued to provide visual aids and technical photography in support of center programs.

Visitor services

In 1979, about 9,000 visitors from 60 countries visited CIMMYT headquarters. Many others visited experiment stations in Mexico where CIMMYT staff conduct research. Ten major conference events, each lasting 1 to 10 days, were handled by the Visitor Services. Over 400 guided tours and slide presentations were given during the year.

Library services

CIMMYT's library (3,465 volumes, 4,204 reprints, 731 serials) continued to offer service to the headquarters staff, doctoral fellows and trainees. It had 2,600 individual users in 1979. The library also has access to the large Mexican National Agricultural Library Collection.

PUBLICATIONS ISSUED BY CIMMYT IN 1979

Title	Language	Pages	Press Run
Administration			
This is CIMMYT	English	32	6000
Este es el CIMMYT	Spanish	32	3180
CIMMYT Today No. 10 Wheat International Testing	English Spanish	15 15	5800 3800
CIMMYT Today No. 11 Off-Season Wheat Nurseries	English	15	5600
Revisión de Programas 1977	Spanish	116	3467
Revisión de Programas 1978	Spanish	144	3963
CIMMYT Review 1979	English	144	4619
Wheat			
CIMMYT Report on Wheat Improvement 1977	English	245	2040
Results of the Second Elite Barley Yield Trials (EBYT) 1976-77 (IB44)	English	38	1000
Results of the Tenth International Bread Wheat Screening Nursery (IBWSN) 1976-77 (IB46)	English	29	1000
Results of the Fifth—Seventh Elite Durum Yield Trial (EDYT) 1974-77 (IB47)	English	46	1000
Results of the Ninth International Bread Wheat Screening Nursery (IBWSN) 1975-76 (IB48)	English	47	1500
Results of the Ninth International Triticale Yield Nursery (ITYN) 1977-78 (IB49)	English	98	1500
Results of the Ninth International Durum Yield Nursery (IDYN) 1977-78 (IB50)	English	75	1500
Results of the Fourteenth International Spring Wheat Yield Nursery (ISWYN) 1977-78 (IB51)	English	98	1500
Results of the First Elite Barley Yield Trial, Hull-less (EBYT) 1977-78 (IB 52)	English	31	1500
Results of the First Elite Barley Yield Trial, Hulled (EBYT) 1977-78 (IB53)	English	44	1500
Maize			
Supplementary Repor-Maize International Testing 1978	English/ Spanish	280	500
Addendum to 1978 Supplementary Report	English/ Spanish	152	500
Miscellaneous			
Visitor's Guide Brochure	English Spanish	1 1	1000 1000
Wheat Training Brochure	English Spanish	1 1	2000 2000
Reprints			
The Magnitude and Complexities of Producing and Distributing the Food Required for a Population of Four Billion	English	59	500
Some Ways International Programs Can Assist Advanced Nations (No.12)	English	8	500
National Production Programs for Introducing High-Quality Protein Maize in Developing Countries (No.13)	English	9	500
Developing Agricultural Research Personnel (No.17)	English	9	500
Instructions for the Management and Reporting of all International Yield and Screening Nurseries	English	17	2000
From Agronomic Data to Farmer Recommendations: An Economics Training Manual	English	50	1093
Aiming Agricultural Research at the Needs of Farmers	English	11	500

DATA PROCESSING UNIT

In 1979, data processing began for principal screening nurseries for each of the four crops of the wheat program (the IBWSN, ITSN, IDSN and EBON), using new programs supplied from the LISA group of Colorado State University. In addition, the various wheat program yield nurseries (ISWYN, ITYN, IDYN and IBYT) were analyzed as in the previous two years.

A complete rewrite of certain components of the maize program package has resulted in greater operating efficiencies and in the breeders being offered some new options in analyzing research data from the international testing program.

Outside the international work, three new computer programs have been written and added to CIMMYT's resources. The first, TABSM, summarizes data from simple sample surveys, and is designed for use on small, simple computers. It already has been found useful by CIMMYT outreach staff. The second program is for the analysis of split-split plot experiments of moderate size. Finally, a new program has been developed to help breeders select lines, in terms of their proximity to the ideal, from multivariate data.

Other aspects of the data processing work, such as the maize germ plasm bank catalogue maintenance and the wheat pedigree books updating, have continued to run smoothly in 1979.

financial statement

Price Waterhouse y Cía.

México, D. F., March 11, 1980

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

In our opinion, the accompanying balance sheets and the related statements of income and expenses 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, 1979 and 1978 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

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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 y Cía

C.P. Francisco González Machado

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

NOTES TO THE FINANCIAL STATEMENTS

NOTE 1 - STATEMENT OF PURPOSE:

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 established 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. Short-term investments are stated at cost, which approximates market.

c. Accounts receivable-Donors - The method of recording pledges recognizes the uncollected portion of the proportional part of the pledge applicable to the current year.

d. Inventories - Amounts are stated at cost (first-in, first-out method) 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 an expenditure. In 1972 the Consultative Group requested that the agricultural centers change to the write-off, then capitalize method of recording purchases of property and equipment. Accordingly, all property and equipment purchased under capital grants as from January 1, 1972, were recorded as an asset and credited to capital grants. Replacements and other property and equipment continued to be recorded as an expenditure of the related program.

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 after fifteen years of services, are recognized as expenses as such premiums accrue. The estimate of the accrued benefit determined on the basis of salaries in effect at year-end amounted to $221,254 in 1979 and $185,290 in 1978 and CIMMYT had recorded a liability of $94,813 in 1979 and $70,875 in 1978. The charge to income for the year amounted to $25,000 in both years including amortization in 10 years of past services.

Other compensation, also based on length of service which may become payable to employees in accordance with the Mexican Labor Law, in the event of dismissal or death, is recorded as an expense of the year in which they become payable.

NOTE 3 - MEXICAN PESO TRANSACTIONS:

At December 31, 1979, CIMMYT had Mexican peso assets and liabilities amounting to Ps34,460,571 and Ps28,591,281 which were included in the balance sheet at the U.S. dollar equivalents resulting from applying the year-end rate of Ps22.67 to the dollar, which prevailed during the year.

The fluctuation of the peso originated translation income aggregating $44,724 in 1979 and $53,022 in 1978 which are credited to accumulated loans, included in the cummulative translation loss amounting to $274,780 at December 31, 1979 and $319,504 at December 31, 1978.

NOTE 4 - OPERATING FUNDS:

The CGIAR permits CIMMYT to maintain in its capital account operating funds equal to thirty days of its core operating budget. Prior to 1979 CIMMYT maintained operating funds of forty days and accordingly, in this year, reduced its operating funds to the limit set by the CGIAR. In addition, prior to 1979, operating funds were called working capital.

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 1979 and 1978. This source of financing will be used again in 1980. After that date, though, activities are expected to be financed from revenue received in the year.

NOTE 6 - UNCOLLECTIBLE PLEDGES:

In 1979, for the first time in CIMMYT's history, a core unrestricted donor was unable to fulfill a pledge. Accordingly, CIMMYT has written off the donation of $100,000 and has charged it against the current year's core unrestricted income.

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

BALANCE SHEET

Currency: US Dlls.

A S S E T S

	As of December 31 1979	As of December 31 1978
Current Assets		
Cash in Hand and in Banks	1,000,462	260,013
Short-Term Investments	350,000	1,319,914
	1,350,462	1,579,927
Accounts Receivable		
Donors (Note 6)	365,743	795,640
Others	1,260,893	975,074
	1,626,636	1,770,714
Inventories	223,971	143,946
Total Current Assets	3,201,069	3,494,587
Fixed Assets		
Vehicles	668,061	653,744
Furniture, Fixtures and Equipment	1,868,209	1,815,257
Buildings	5,067,517	5,010,564
Land	464,123	464,123
Other Fixed Assets	371,487	371,487
Total Fixed Assets	8,439,397	8,315,175
Other Assets		
Guarantee Deposits	1,257	1,260
Deferred Charges	71,579	27,178
Total Other Assets	72,836	28,438
TOTAL ASSETS	11,713,302	11,838,200

LIABILITIES, CAPITAL GRANTS, UNEXPENDED FUNDS AND RESERVES

	As of December 31 1979	As of December 31 1978
Current Liabilities		
Bank Loans	441,112	
Vouchers Payable	525,878	568,626
Accrued Payroll	95,908	112,082
Accrued Taxes	197,667	169,448
Accrued Miscellaneous Expenses	251,015	175,154
Accounts Payable - Donors	68,720	130,079
Total Current Liabilities	1,580,300	1,155,389
Capital Grants, Unexpended Funds and Reserves		
Capital		
Fully Expended in Fixed Assets	8,439,393	8,315,171
Operating Funds (Note 4)	1,215,000	1,340,000
	9,654,393	9,655,171
Unexpended Funds (Note 5)		
Core Unrestricted	538,381	1,257,944
Core Restricted	19,052	19,052
Extra Core and Cooperative Projects	(47,780)	(3,355)
Auxiliary Services	(16,531)	(18,764)
	493,122	1,254,877
Translation Effect (Note 3)	(274,780)	(319,504)
Trustee Reserve	92,267	92,267
Contingency Reserve	168,000	
Total Capital Grants, Unexpended Funds and Reserves	10,133,002	10,682,811
TOTAL LIABILITIES AND CAPITAL	11,713,302	11,838,200

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

COMPARATIVE STATEMENT OF REVENUE AND EXPENSES

Currency: US Dlls.

	1979	1978
REVENUE		
Grants	15,607,796	13,540,146
Administrative Fees	634,810	739,079
Sale of Crops	30,612	21,560
Interest on Investments in Marketable Securities	116,419	81,373
Auxiliary Services	410,463	300,025
Other Income	2,089	2,837
TOTAL REVENUE	16,802,189	14,685,020
EXPENSES		
Research Programs	10,673,313	8,729,314
Conferences and Training	2,349,432	2,136,064
Information Services	473,300	509,815
General Administration	1,360,822	1,207,158
Plant Operations	1,447,333	1,229,463
Capital Acquisitions	124,222	80,451
Auxiliary Services	408,230	338,018
Indirect Costs	659,292	758,701
Statutory Terminal Pay Funds	25,000	25,000
Operating Funds	(125,000)	230,000
Contingency Reserve	168,000	
TOTAL EXPENSES	17,563,944	15,243,984
EXCESS OF EXPENSES OVER REVENUE	(761,755)	(558,964)
Translation Effect for the Year	44,724	53,022
TOTAL EXPENSES OVER REVENUE	(717,031)	(505,942)
Unexpended Funds, Opening Balance	1,254,877	1,813,841
Accumulated Translation Effect, Opening Balance	(319,504)	(372,526)
Closing Balance Unexpended Funds and Accumulated Translation Effect as per Balance Sheet	218,342	935,373

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

STATEMENT OF CHANGES IN FINANCIAL POSITION

Currency: US Dlls.

	Year Ended December 31	
	1 9 7 9	1 9 7 8
Financial resources were provided by:		
Revenue	16,802,189	14,685,020
Capitalization of Fixed Assets purchased in the year	124,222	80,451
Increase in Contingency Reserve	168,000	
Increase in Operating Funds		230,000
Translation Effect for the year - Net	44,724	53,022
	17,139,135	15,048,493
Financial resources were used for:		
Expenses	17,563,944	15,243,984
Less - Expenses not requiring working capital in the year:		
Amortization of Deferred Charges	(19,324)	
Working capital used for the operations for the year	17,544,620	15,243,984
Purchases of Fixed Assets	124,222	80,451
Increase in Other Assets	63,722	27,179
Decrease in Operating Funds	125,000	
	17,857,564	15,351,614
(Decrease) in Working Capital	(718,429)	(303,121)

Analysis of Changes in Working Capital Accounts

	1 9 7 9	1 9 7 8
Cash in Hand and in Banks	740,449	21,303
Short-Term Investments	(969,914)	(203,338)
Accounts Receivable:		
Donors	(429,897)	(600,777)
Others	285,819	(135,028)
Inventories	80,025	5,956
Bank Loans	(441,112)	
Vouchers Payable	42,748	514,362
Accrued Payroll	16,174	35,325
Accrued Taxes	(28,219)	(23,407)
Accrued Miscellaneous Expenses	(75,861)	(107,031)
Accounts Payable - Donors	61,359	189,514
(Decrease) in working capital	(718,429)	(303,121)
Working capital at beginning of year	2,339,198	2,642,319
Working Capital at end of year	1,620,769	2,339,198

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Location and elevations of experiment stations in Mexico at which CIMMYT conducts research (■ stations of the Instituto Nacional de Investigaciones Agricolas).