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CIMMYT
Report on Maize Improvement
1980-81

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1/ Left 1981
2/ Left 1980
3/ To Mexico from Regional Post 1980
4/ To Regional Post 1980

Introduction

This report, intended primarily for our scientific cooperators and for maize workers around the world, presents data from CIMMYT maize research, training, and international testing during the years 1980-81.

CIMMYT's research emphasis in maize improvement continues to be on the development and improvement of normal and high-quality protein broad-based gene pools and populations. We have, accordingly, designed and implemented a continuous improvement system, whereby a wide range of materials is aggregated in gene pools for lowland, intermediate, high altitude and temperate environments. These materials are then improved to the point of being genetically ready to contribute superior new germplasm to more advanced populations. This approach, implemented in close association with national programs, has generated materials that meet specific, developing-country requirements with superior open-pollinated varieties, white or yellow, flint or dent, early, intermediate or late in maturity, with high and dependable yields equal or superior to the best commercially available materials.

Although CIMMYT emphasizes the use of varieties, they are not emphasized to the exclusion of hybrids. CIMMYT populations have proven beneficial to national hybrid breeding efforts also, where the requisite infrastructure exists to sustain such programs.

Multilocational testing plays a major role in CIMMYT's maize improvement system. In Mexico, CIMMYT has a network of experiment stations located in several distinct maize-growing environments that are representative of several of the major maize environments found in other parts of the developing world. These differing environments permit CIMMYT to carry out preliminary stages of germplasm improvement for a wide range of production circumstances. In addition to Mexico's environmental diversity, its climate permits CIMMYT scientists to conduct two crop improvement cycles per year at its lowland and intermediate altitude stations. CIMMYT's maize populations enter the international testing program once the judgment is made that they have reached a level of development sufficiently high to offer superior germplasm for some part of the developing world.

The following pages report on germplasm development, including that of high-lysine maize, on various research projects, including regional ones and those concerning wide crosses, and on the various training activities related to maize.

Gene Pool Development

CIMMYT's gene pool development unit continues to 1) evaluate and use superior maize materials (introductions) from around the world, 2) maintain a working germplasm bank, and 3) create and improve gene pools of different maturities, grain colors, and textures. Superior introductions and bank accessions are systematically evaluated and added to the appropriate gene pools in order to improve them and extend their genetic diversity. Superior half-sib families of gene pools are identified and transferred to corresponding existing advanced unit populations in order to make them more useful for our collaborators, or are used to form new advanced populations.

Maize Germplasm Bank

At the end of 1981, the germplasm bank held over 12,000 accessions of maize, which comprise the extreme variation found within this species in the Americas and parts of Asia. The germplasm bank conserves these materials for use by scientists around the globe with serious interest in basic or applied research.

Regeneration of materials

Seed is frequently removed from the bank for use both at CIMMYT and overseas, necessitating regeneration of an accession when the amount falls below 500 grams. Presently 270 plants of an accession are bulk-pollinated to rejuvenate each material. In 1980-81, 748 accessions were regenerated from the tropical and temperate areas. In addition, 100 materials were sent to the Pioneer Seed Company (USA) for regeneration in 1981. A total of 150,000 hand pollinations were made and over seven hectares of land used.

Bank observation nurseries

The major contribution of the germplasm bank to maize improvement is the provision of new sources of genetic variation. In order to use these materials efficiently, multisite observation nurseries are invaluable for identifying promising materials. Materials are grown along with suitable pools as checks, and data are taken at each site throughout the growing season. Such characteristics as

CIMMYT scientists discuss criteria used in selecting superior maize ears for the next cycle of gene pool improvement.

maturity, disease reactions and plant and ear height are considered together with the yield of each accession. At harvest, accessions are selected on the basis of their across-site performance. Three hundred materials were evaluated in 1980, and the ones selected were introduced into appropriate gene pools.

Services rendered
Accessions from the germplasm bank are requested both by maize workers overseas and CIMMYT personnel. A quantity of seed sufficient for evaluation and increase is offered for each request. The germplasm bank fulfilled 72 seed requests in 1980 and 1981, sending 966 samples to 24 different countries (Table 1). These accessions have been used for studies in evolution, breeding, chemotaxonomy, identification of chromosome knobs, and disease resistance.

Introduction Nurseries

Superior maize materials from various national programs are evaluated at several locations within Mexico in one-row plots 5 meters in length. They are studied for all agronomic attributes including maturity, height, yield potential, and reaction to insects and diseases.

During 1980-81, over 550 introductions from tropical lowland and temperate areas were evaluated, with appropriate pools as checks, and the superior ones were incorporated into the appropriate gene pools (Table 2). New materials were especially desired for earliness and insect and disease resistance.

Gene Pools

A gene pool may be defined as a mixture of diverse germplasm, undergoing continuous recombination, from which materials can be taken and to which materials can be added. CIMMYT recognizes the need for gene pools for three broad ecological zones, tropical lowlands, subtropical-temperate, and tropical highlands. Within each of these zones, pools are characterized in terms of general maturity range, early, medium, and late, grain color, white and yellow, and grain texture, flint, dent and floury (for more information on classification and composition of various gene pools, refer to the CIMMYT Report on Maize Improvement, 1973). There are 12 gene pools for the tropical-lowland zone, eight for the subtropical-temperate zone (with the omission of the late maturity group), and seven for the tropical highlands.

Two guidelines followed in the recombination and improvement of gene pools are:

- Low selection intensity applied to the within-gene component of pool improvement, and
- Provision for systematic introgression of additional superior germplasm into the pool.

The half-sib method of selection, as modified by CIMMYT, is used. Approximately 500 half-sib families making up a gene pool are planted in an arrangement of 2 females to 1 male. All female rows and undesirable male plants are detasseled. In the summer season, when each pool is grown at more than one site, superior families are identified at each location by a team of scientists from various disciplines. Yield potential, height, maturity, lodging, disease and insect reaction, and uniformity are taken into account at appropriate stages of plant development. Best plants are identified at each location only in those families which have performed well at all locations. At harvest, the best ear is chosen from the selected plant for each pool at each site. The selected ears, individually, form the half-sib families and a balanced mixture of them forms the male rows (pollen source) of the next cycle's planting.

In addition, ears found greatly superior at only one site are also retained to provide superior recombinants for the future. They are planted as female rows only. Their seed is not included in the male composite. In winter, when pools are planted, generally at only one site, relatively mild selection intensity is applied.

Selected introductions and the germplasm bank entries are planted only as female rows. This avoids the possibility of unproven materials contaminating the pool, and provides the opportunity to compare the new sources with the pool while they are being crossed to it. Their superior progenies are harvested, and they are again planted as female rows in the next cycle to obtain an indication of the combining ability of the new entry with the pool. Superior introductions are then identified and incorporated in the next cycle, using their remnant seed or seed of crosses with the pool.

Tropical gene pools
The tropical lowland gene pools were planted at Poza Rica (lat. 21°N, alt. 60 m) during the summer and winter, and at Obregon (lat. 28°N, alt. 39 m) during the summer of 1980. No plantings were made at Obregon in 1981. Early tropical pools completed ten cycles of improvement at the end of summer, 1981. In these pools, approximately 1,500 of the earliest silking plants were identified in each season. At harvest, the best and relatively drier ears were selected, the intent being to select genotypes with faster rates of grain filling and drying down. The female rows were completely detasseled when 70 percent of the females had silked to ensure that selected female plants did not receive pollen from late male plants. In addition, late female plants produced no grain and were automatically eliminated by this system. Thus, if insufficient ears were available from selected plants, more could be selected from other plants without fear of introducing late germplasm into the pool.

Early materials should be planted at higher plant densities in order to realize their true economic potential. Planting at high density, however, can result in increased barrenness and more lodging. The early tropical materials were, therefore, improved for their tolerance to high plant density. These pools were planted in the system of 2 females to 1 male. The males, however, were planted at double the density of the females, and tall, late, lodged, diseased, or poorly coinciding (stigma and pollen production) plants were detasseled. At harvest, ears from only agronomically superior plants from the female rows were selected. Selection for tolerance to high plant density in these pools will continue.

Tropical gene pools of intermediate and late maturity had undergone fourteen cycles of half-sib recurrent selection by the end of 1981, with the exception of Pool 22 which had completed fifteeen cycles. In addition to their improvement for general agronomic characteristics and resistance to various diseases, a program begun in the summer of 1978 to upgrade the level of resistance to a specific disease or insect in each of these pools was continued. The insect or disease chosen to be combated in a pool was the most formidable pest confronting the pool in the area of its adaptation. The pests, and the procedures followed to improve resistance to them, are discussed in the section Insect and Disease Resistance in Pools.

Subtropical gene pools
The subtropical-temperate gene pools were planted at Tlaltizapan (lat. 19°N, alt. 940 m) during summer and winter, and at Obregon during the summer season of 1980. No planting was made at Obregon in 1981. Pools 27, 32, 33 and 34 had undergone 15 cycles of improvement by the end of 1981, pools 29, 30 and 31 nine or ten cycles, and pool 28, nine cycles. The early pools were handled in a manner similar to that of the early tropical pools, and the ones infested and inoculated are discussed in the section Insect and Disease Resistance in Pools. These pools were also planted at Poza Rica during the winter of both years to broaden their adaptation and disease resistance.

Highland gene pools
The highland gene pools are being improved in collaboration with the maize program of INIAP Ecuador where one CIMMYT maize staff is stationed. The pools are grown once a year at El Batan (lat. 20°N, alt. 2,249 m) and Toluca (lat. 20°N, alt. 2,640 m). The planting is done during the last week of March and the first week of April. At El Batan half of each half-sib family is artificially infested with ear worms [*Heliothis zea* (Bodie)] and, at Toluca, half of the same families are artificially inoculated with fusarium ear rot. Ear rots and ear worms are two of the major pests of maize in the highlands of Latin America.

The early pools are harvested in Mexico in September and sent to Ecuador for planting. They are harvested in April in Ecuador and sent back to Mexico for immediate planting. Thus, these materials undergo two cycles of improvement each year under this program of multilocation recombination and selection.

Some of the late gene pools are also infested and inoculated in Mexico and planted both in Mexico and Ecuador as outlined above, but their growing cycle is too long to obtain two cycles a year. Selections from one country are merged into those of the other approximately a year later.

In order to further broaden the base of germplasm available in the highlands of South America, several materials with floury and morocho seeds were crossed with temperate maize types. The results of such a cross would make available to farmers of this region their preferred seed types on plants more efficient in grain production. This material has now completed four cycles of recombination with selection at El Batan, Toluca,

and Tlaltizapan, and it appears possible to combine the two attributes. This effort will have to continue for several additional cycles, before commercially useful products are available. (For further information, see Regional Programs, Andean Regional Program, page 79 of this publication.)

New gene pools

Maize programs in the USA and Europe, where a major portion of total maize is produced each year, have a rather narrow genetic base. This not only makes the crop more vulnerable to unforeseen environmental vagaries, but also limits the scope of its improvement in the future. Better exchange of improved materials among scientists, and introgression of exotic germplasm into their breeding materials, would certainly alleviate some of the problems of a narrow gene base.

This realization among the maize workers at the EUCARPIA meetings held in 1977 at Krasnodar (USSR) led CIMMYT to form three broad-based gene pools:

- Gene pool for the Northern Temperate Region
- Gene pool for the Intermediate Temperate Region
- Gene pool for the Southern Temperate Region

The gene pool for the NTR is based on materials from the US Corn Belt; the pool for the ITR is composed primarily of maize materials from Europe, and the pool for the STR is based on materials from the US Corn Belt and tropical lowlands and highlands.

The NTR gene pool was grown in the summer for two years in Mexico, the ITR in Mexico and the USA (Cornell and Minnesota), and the STR only in Mexico. In addition, the CIMMYT-German Maize Exotic Gene Pool formed during 1976 was grown in Mexico, Poland, Switzerland, and Germany. These pools were evaluated and recombined in the summer of each year in the countries mentioned above, and selections made at each site. Earliness, standability, cold tolerance, and yield are among the characters considered during selection. These selections were then recombined in the winter of each year at Tlaltizapan. Excellent progress has been made in accumulating these traits in the pools, and the material grows successfully at every evaluation and selection site.

These gene pools will serve as new sources of variation for the temperate areas and will provide a mechanism for transfer of genes from tropical to temperate areas and vice-versa. These pools will also prove valuable to many of our cooperators in Asia and Africa.

Insect and disease resistance in pools

As mentioned earlier, several pools were infested or inoculated artificially both years. Artificial infestation or inoculation results in more uniform and timely application of inoculum than can be achieved under natural conditions and, thus, in faster improvement of resistance. Pools 33 and 34 were chosen for improving their resistance to ear rots (see Table 3d), and Pool 32 for southwestern corn borer (SWCB), *Diatraea grandiosella* (Dyar.). Tropical Pools 22 and 23 were inoculated with stalk rot (see Tables 3b and 3c), and Pools 20 and 25 with ear rot pathogens (see Table 3a). Pools 24 and 26 were infested with fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith). Pools 19 and 21 could not be infested with sugarcane borer (SCB), *Diatraea saccharalis* (F.).

Half-sib selection, as modified by CIMMYT, permits application of selection pressure in the male rows for all those characters which can be identified prior to flowering. This is accomplished by detasseling the male plants considered undesirable, and was practiced in the pools infested with FAW, SWCB, and SCB.

FAW infestation was done in the seedling stage and both plants per hill were infested. At thinning, done 2 to 3 weeks after infestation, the more susceptible seedling was removed from each hill. In this way approximately 50 percent of the susceptible plants were eliminated from the male rows before pollen shed. Half of each female row (8 hills, 16 plants) was also infested. The protected half of the row served as a check for comparing agronomic characters affected by insect damage within each family, such as plant height, maturity, and yield.

All infestations were done with newly hatched larvae (first instar) mixed in ground corncobs as an inert carrier and applied in the plant whorls with a larva dispenser ("bazooka"). This application was done when the plants reached 3 to 4 leaves fully extended, at a rate of about 40 larvae per plant. Infestations were done in split applications to achieve better uniformity.

Approximately two weeks after infestation, visual ratings for insect damage were made on a family basis, and the more susceptible plants were eliminated. Within superior noneliminated families, plants showing little or no damage were tagged for resistance. At harvest, ears were selected from both the protected and infested halves of the families. Selection of ears from superior plants in the protected half of an otherwise susceptible family reduced the chances of narrowing the broad genetic base of the pool by favoring a single character too strongly. While emphasis was given to selecting ears from tagged plants if they were acceptable for other characters, ears from nontagged plants (not originally selected because of more feeding damage) were also selected, if ear size indicated the plant was able to tolerate the feeding damage. In this manner, selection among and within families included plants with both types of resistance, those which had less feeding damage (antibiosis) and those which were able to recover and produce well in spite of some damage (tolerance).

More recently insect work was started in highland maize. Resistance to the corn earworm (CEW), *Heliothis zea* (Bodie), would be of great benefit to farmers in the highlands of Latin America. For CEW the same infestation technique was used. As CEW damage occurs after pollination, selection was done only in female rows. Again, only half the plants in the female rows (the earlier ones) were infested. At harvest, less damaged ears from infested plants, and ears from agronomically superior noninfested plants, were saved for succeeding generations. In 1980 and 1981, Pools 1 and 3 were infested and selected in the manner described above.

In pools chosen for improving resistance to rot-causing pathogens, eight plants, half of each family, were inoculated. As the inoculations are carried out in the field where environmental factors affecting rots cannot be controlled, this technique of partial inoculation eliminates the possibility of drastic genetic erosion in the pools as a result of complete or nearly complete rotting of the plants inoculated.

As ear rot-causing pathogens, two fungi, *Diplodia maydis* (Berk.) Sacc. and *D. macrospora* Earle, were chosen. The inoculum was raised on sterilized oat kernels in one-liter jars, incubating both species in the same vessel, but on opposite sides. For inoculations, spore suspensions in water supplemented with a few droplets of a detergent (Tween 80) were prepared, and after the spore concentration was adjusted to 50,000 to 150,000 spores/ml (according to the susceptibility of the material to be inoculated) plants were inoculated when the silks began to dry. The main ear of the plant was inoculated using plastic spray bottles calibrated to 2 ml/discharge. One discharge was applied on the silk, and the other between the husk leaves.

In conformity with the variation of maturity and the growth rate of the plants, inoculations were done at appropriate intervals to ensure a timely infection of the ear. Plants were marked with different tags for each inoculation date in order to help disclose variation in the development of rot on different days, and any dissimilarities were taken into consideration at harvest time. Also for determination of those differences, a number of plants in male rows were inoculated, representing the mean of the population. In some cases, selected plants of the male rows were inoculated with the inoculum at up to five times higher concentration than that used in female rows, and clean ears selected from agronomically superior plants were added to the pool in following cycles as female entries. These additional selections support the upgrading process in improving for rot resistance. In female rows, only clean or nearly clean ears were retained from agronomically acceptable plants, and ears from more susceptible progenies, as indicated by family readings, were either neglected or used as female entries only in the following cycle.

For stalk rot inoculations, *Fusarium moniliforme* Shed. was grown on toothpicks which were inserted into the first elongated internode after drilling a hole in it, at the same physiological stage of the plant as for ear rots. Whenever possible, stalks were split at harvest and as many ears as possible were retained from agronomically acceptable plants with little or no rot. Otherwise, selections were based on ear appearance. Ears with poorly filled tips and loose kernels, an indication of stalk rot infection, were rejected.

In order to measure the efficiency of selections in improvement of insect or disease resistance, as well as in agronomic characteristics, such as yield, plant height, and maturity, eight groups of families were identified in each pool at the end of 1979 (see CIMMYT Report on Maize Improvement, 1978-79).

In 1980, remnant seed of families belonging to each of these eight groups was intercrossed, and these resulting groups were evaluated in both the summer and winter of that year. A summary of these evaluations is shown in Tables 3a, b, c and d (referred to earlier) for different characters. The yield, plant and ear heights, and days to silk have not been affected by selecting for disease resistance, either in ear or stalk rot selections. There was also a tendency for groups with three cycles of selection from inoculated plants (RRR) of the families to be significantly more resistant than those with families where selection was from noninoculated plants (rrr) of the families.

Preliminary Evaluation Trials (PETs)

PETs were conducted during 1979 primarily to evaluate the performance of gene pools not already in the International Testing Program. As indicated, these pools are handled in Mexico and are at various stages of development. Evaluating them in various national programs would not only help identify potential areas of their adaptation but also the problems which should receive priority in their improvement. The populations already being improved in the International Testing Program were also included in these trials to better establish the correspondence between them and their respective back-up pools.

Three separate PETs were constituted. PET-1 consisted of seven early tropical materials currently under improvement, PET-2 of 28 medium and late-maturing tropical entries, and PET-3 of 15 subtropical and temperate materials of various maturities. The three trials had space for three, two, and three local checks, respectively. Randomized complete block design with four replications was used in each case. Four-row plots with 75 cm between rows and 50 cm between hills were used. The stand was thinned to two plots per hill at three-to-four leaf stage. The data (Tables 4a, b and c) indicated that the pools compared favorably with their corresponding populations in yield, height, and maturity at the locations tested.

CIMMYT Maize Gene Pools

Pool 1. Highland early white floury
Based primarily on the race Cacahuacintle of Mexico, this pool includes germplasm from the highlands of Colombia, Bolivia, Peru, Ecuador, and Mexico. A small proportion of the germplasm also comes from the temperate areas of the USA and Europe. Selection emphasis is for large floury seeds and resistance to ear rots and earworms.

Pool 2. Highland late white floury
Based mainly on the races Cuzco Gigante of Peru and Hualtaco of Bolivia, this pool has germplasm from Kenya and Cuba. Selection is being practiced for large floury seed and resistance to ear rots and earworms.

Pool 3. Highland early yellow floury
This pool is based essentially on the same germplasm as is Pool 1, except that yellow floury kernels have been selected. Selection is being practiced for the same traits as in Pool 1.

Pool 4. Highland late yellow floury
Based primarily on race Chillo of Ecuador, this gene pool is being selected for large floury seeds and resistance to ear rot and ear worm. Additional germplasm in this pool is from the highlands of Andean countries, Mexico, Africa, and the USA.

Pool 5. Highland early white morocho
This gene pool is based on early white morocho (seed with hard flint outside and soft inside) genotypes of Peru, Bolivia, Colombia, and Ecuador, with some germplasm from Mexico, the USA, and Europe. Selection is being practiced for large seed type and resistance to earworms and ear rots.

Pool 6. Highland early yellow morocho
This gene pool is based on early yellow morocho genotypes from the same Andean countries as Pool 5. It also has germplasm from the highlands of Mexico and Africa, and from the USA, Europe, and Indonesia. Selection is being practiced for the same traits as in Pool 5.

Pool 7. Highland late white morocho
Originally a mixture of late white and yellow morocho types from the highland areas of the Andean countries, it was changed, in 1982, to a white pool. Some of its germplasm also comes from the highlands of Mexico and Africa, and from the USA. Selection is being practiced for better seed type and resistance to ear rots and earworms.

Pool 8. Highland late yellow morocho
This pool was formed with the yellow segregates selected from Pool 7.

Pool 9. Highland late white dent
Developed by crossing materials well adapted to the African highlands, this pool's germplasm includes materials from the Kenyan highlands, collections of races from Colombia, Ecuador, Guatemala, and tropical lowland Tuxpeño from Mexico. It is late and tall. Selection is being practiced for resistance to foliar diseases.

Pool 15. Tropical early white flint
This pool is based on crosses among a large number of early and late white flint materials from Mexico, the Caribbean area, Central and South America, and Asia. Selection is being practiced for early maturity and better plant type while trying to maintain yield. In addition, the pool is being improved for tolerance to high plant density and stalk rot.

Pool 16. Tropical early white dent
White dent materials were used in forming this gene pool from the same geographical areas as Pool 15. Selection is being practiced for early maturity and better plant type while trying to maintain yield, tolerance to high plant density, and resistance to stalk rot.

Pool 17. Tropical early yellow flint
This pool is the same as Pool 15 except that yellow flint materials were used in its formation.

Pool 18. Tropical early yellow dent
This pool is the same as Pool 17 except that yellow dent types were used.

Pool 19. Tropical intermediate white flint
Nearly 30 percent of the germplasm of this white flint gene pool is contributed by materials with downy mildew resistance from the Philippines. It also has materials from Cuba, Mexico, Argentina, Honduras, El Salvador, Colombia, Ecuador, India, and central and southern USA. It is intermediate to late in maturity and has good plant type and yield potential. Selection is being practiced for improved shelling percentage and resistance to the sugarcane borer, *Diatraea saccharalis* (F.).

Pool 20. Tropical intermediate white dent
This intermediate white dent gene pool is made mainly of materials from the Philippines, India, and Southeast Asia. A small fraction of germplasm is also from Mexico and various Central American countries. The pool is similar in plant type and yield to Pool 19 and is being specifically improved for ear rot resistance.

Pool 21. Tropical intermediate yellow flint
This gene pool is based on yellow flint materials from Mexico, Cuba, the Dominican Republic, Colombia, Argentina, Ecuador, Costa Rica, Uruguay, St. Vincent, Guatemala, Surinam, and India. This pool is relatively more tolerant of stunt and is intermediate in maturity. Selection emphasis is on improved shelling percentage and sugarcane borer resistance.

Pool 22. Tropical intermediate yellow dent
Made up of materials from Mexico, Cuba, The Dominican Republic, Antigua, Brazil, Peru, Ecuador, Argentina, Colombia, India, Puerto Rico, and several Central American countries, this pool has good yield potential and plant type. It is being improved specifically for stalk rot resistance.

Pool 23. Tropical late white flint
Based on white flint selections from crosses among materials from Mexico, Colombia, the Caribbean area, Guatemala, Panama and other Central American countries, India, Thailand, and the Philippines, this pool is late in maturity and has relatively short plants and excellent yield. Selection is being practiced for increased stalk rot resistance.

Pool 24. Tropical late white dent
This gene pool, based mainly on Tuxpeño germplasm from Mexico, has some materials from Central America, the ones late in maturity. It is being selected specifically for increased resistance to fall armyworm (*Spodoptera frugiperda* [J.E. Smith]).

Pool 25. Tropical late yellow flint
This gene pool, made up of materials from Mexico, Central America, the Caribbean area, Ecuador, Colombia, and Argentina, is relatively tall in plant type and has good yield potential. Specific selection is being practiced for ear rot resistance.

Pool 26. Tropical late yellow dent
This pool is made up of materials from Central America, Mexico, Asia, Colombia, and the Caribbean area. A small fraction of total germplasm is also from the US Corn Belt. It is relatively more tolerant to stunt, is tall, and has good yield potential. This pool is being selected for increased fall armyworm resistance.

Pool 27. Temperate early white flint
This subtropical early white flint pool is made up of materials from Pakistan. It also has germplasm from the USA, China, Lebanon, and several European countries. It is variable in plant type and other agronomic characters but has good yield potential. Selection is being practiced for tolerance to high density and for resistance to ear and stalk rots and leaf diseases.

Pool 28. Subtropical early white dent
Based on white dent selections from crosses between white flint materials from Pakistan, and yellow flint and dent materials from Europe, China, Lebanon, Mexico, Guatemala, and the US Corn Belt, this pool has undergone only a few cycles of selection and is therefore more variable than some older pools. It is early in maturity and has good yield potential. Selection is being practiced for tolerance to high density, and for resistance to ear and stalk rots and leaf diseases.

Pool 29. Temperate early yellow flint
This early yellow flint gene pool has excellent plant type and yield. It is based on materials from Europe, Lebanon, the US Corn Belt, China, Pakistan, Indonesia, and South America. It is being improved for tolerance to high density and for resistance to ear and stalk rots and leaf diseases.

Pool 30. Temperate early yellow dent
Made up of materials from Europe, China, Lebanon, Mexico, South America, and the US Corn Belt, this pool is early in maturity and has good plant type and yield. It is being improved for tolerance to high density and for resistance to ear and stalk rots and leaf diseases.

Pool 31. Temperate intermediate white flint
This medium-maturity pool is based on white flint segregates from crosses among materials from Mexico, the US Corn Belt, Brazil, Uruguay, Argentina, China, Pakistan, Yugoslavia, Lebanon, Guatemala, Venezuela, Peru, Cuba, Antigua, and the Dominican Republic. It is relatively uniform in plant height and maturity and has good yield potential. It is being improved for resistance to leaf diseases and ear and stalk rots.

Pool 32. Temperate intermediate white dent
This pool has the same gene base as Pool 31 but is better in plant type and yield. It has deep white dent kernels and is being selected for increased resistance to the Southwestern corn borer, *Diatraea grandiosella* (Dyar).

Pool 33. Temperate intermediate yellow flint
This pool is the same as Pool 31 except that yellow-orange flint kernels have been selected. This pool is being selected for increased resistance to ear rot, stalk rot, and leaf diseases.

Pool 34. Temperate intermediate yellow dent
This intermediate yellow gene pool is made up of crosses among Mexican lowland and highland materials and materials from the US Corn Belt, southern USA, Yugoslavia, Hungary, China, Lebanon, Guatemala, Honduras, Chile, Antigua, Cuba, the Dominican Republic, Peru, and Pakistan. It has short plant type, well-placed ears, and good yield potential. Selection is being practiced for resistance to ear rot, stalk rot, and leaf diseases.

Gene Pool for the northern temperate region (NTR)
Based primarily on US germplasm, but also including materials from China, Korea, and Lebanon, this gene pool is designed to serve maize growing areas 46-52° N and S of the equator. It also offers useful germplasm for the winter maize growing areas of lower latitudes. Selection is being practiced for early maturity, ability to grow under cold conditions, and resistance to leaf diseases and ear and stalk rots.

Gene Pool for the intermediate temperate region (ITR)
Based on materials from Bulgaria, Spain, Hungary, France, Turkey, Yugoslavia, Pakistan, Poland, and Germany, this pool is designed to serve the maize growing areas of the intermediate temperate range (40-46° N and S) and also the winter maize-growing areas of the tropics and subtropics. Selection is practiced for the same traits as in the NTR pool.

Gene Pool for the southern temperate region (STR)
Based on germplasm from tropical (both lowland and highland), subtropical, and temperate areas of Mexico, Pakistan, the USA, Africa, Central America and the Caribbean area, and Bolivia, this pool is designed to serve winter maize-growing areas of the tropics and subtropics and low-latitude temperate areas (34° to 40° N and S). Selection is being practiced for earliness and resistance to leaf diseases and ear and stalk rots.

CIMMYT-Germany maize gene pool
This gene pool is the result of an effort to introduce tropical germplasm into temperate areas. It is being handled in cooperation with the University of Hohenheim, Germany. It is based on germplasm from Mexico, Peru, Bolivia, Pakistan, China, Hungary, the USA, and Yemen. Selection is being practiced for earliness, standability, ability to grow under cold conditions, and resistance to leaf diseases.

Table 1. Countries requesting seed shipments by CIMMYT's Maize Germplasm Bank, 1980 and 1981

Country	1980 No. of shipments	1980 No. of items	1981 No. of shipments	1981 No. of items	Country	1980 No. of shipments	1980 No. of items	1981 No. of shipments	1981 No. of items
Argentina	2	48	1	2	Indonesia	1	2	1	5
Brazil	-	- -	2	13	Kenya	1	2	-	- -
Canada	-	- -	2	9	Mexico	8	50	3	205
China	-	- -	1	12	New Zealand	2	33	1	11
Colombia	1	23	-	- -	Nigeria	1	38	-	- -
Costa Rica	-	- -	1	26	Peru	1	7	-	- -
England	1	26	-	- -	Philippines	-	- -	1	4
Ethiopia	-	- -	1	2	Poland	1	17	-	- -
France	3	39	1	1	USA	12	56	10	170
Germany (East)	1	3	-	- -	USSR	-	- -	1	10
Germany (West)	2	48	-	- -	Yugoslavia	1	2	-	- -
Holland	3	70	-	- -					
India	2	15	3	17	Total	43	479	29	487

Table 2. Materials added to the CIMMYT gene pools, 1980-81

Pool number	Introductions
15	Sili Sujen, Jaune Flint, IP6, D771, SS2, PMC (W), Phil DMR2, Buland Shahar (W), Suwan 2, D741, Changez, Suwan 1. Impa Impa, Pak. Precoz, Moghyr, Tulbulia, Tinpakhiya, IP8
16	Sili Sujen, Jaune Flint, D741(W), D742, Buland Shahar (W), Changez, Sarhad, IP8, IP3, IP4, Tiniguib, SS2, Phil. DMR2, D771, H62, Impa Impa, D783, Dasana, SS2, Syn. P.K., BS10 Mo17, IA SSSE VI, Suwan 2, Suwan 1, Sarhad, Phil. DMR4
17	Jaune Flint, Suwan 2, B57, H51, B73, Mo17, B79, BSL, BS13, A670, BS11, D771, D741, Syn. 551, J603. FRB73, ETO (M), IP5, UP yellow local, Suwan 4, Kretek, Farrukkhabad local
18	Sili Sujen, Jaune Flint, D765, Suwan 2, D741, Mo17, BSSS (R)C8, H51, H84, H98, H101, Sarhad, PR7535, BSL, BS10, BS13, BS16, FR Mo17, FRB73, Sarhad, Comp. Sel. Precoz, IP5, IP7, Suwan 1, Prolific DMR
19	PK Across WSS2, Yuzpsc 71C, TC1, IP8, SS2, Changez, Suwan 1, D742, Soan, Phil. DMR, CM600, D741W, Pakelo, Suwan 1 W, Biasa, Menado Putih, OB7532, Sarhad, IP4, IP3, Phil. DMR2, FRB73, B79, BS10, BS13
20	El Salvador 9, 41 and 50, Tuxp. C17, Suwan 1 W, ETO LT C6, D772, Across 7442, OB7532, Laxami, Mo14 W, FRK55 CI66, FR804 W, FR805 W, BS10, Prolific DMR, Suwan 2, CM600, Dholi 7722, MS (I) DR, CM400, CM300, Kahil TC1, Changez, Sarhad, IP4, Soan
21	J54, Suwan 1, J603, ETO CBC, Phil. DMR1, CM115, B79, FRB73, BS11, BSSS (R) C7, BS10, BS13, Am. Bajio, BS16

Table 2. (Cont'd)

Pool number	Introductions
22	J54, Suwan 1, BS16, FR13, FRB73, Am. Bajio, B79, FR Mo17, Suwan 2, B23, Sarhad, L4, Pioneer X 440, B68, BSSS (R) C7, Tuxp. C17, ETO LT C6, H96, Syn. 551, VL42, BS11
23	Suwan 1, Tuxp. C17, ETO LT C6, MSI (DR), D772, Phil. DMR2, Across 7442, OB7532, D742, Laxami, Dholi 7722, CM400, CM300, Sarhad, IP4
24	Tuxp. C17, ET LT C6, MSI (DR), D772, Across 7442, OB 7532, D743, Laxami, Dholi 7722, Mo14 W, Mo1 W, FRK55, CI66, FR804 W, FR805 W, T115, T139, T143, Sarhad
25	J54, Suwan 1, J603, Sarhad, B23, BS16, ETO CBC, Suwan 2, D741, IP5, Phil. DMR1, FRB73, CM115, B79, BS11, L4, BSSS (R) C7, OB7446
26	Rep. Dom. 169, 241, 242 and 254, J54 Suwan 1, J603, Sarhad, B23, BS16, Indonesia CB, ETO-CBC, FR13, FR13A, FRB73, H98, CM115, B79, Am. Bajio, B57, FR Mo17, L4, BSSS (R) C7, BS10
27	Burdek, Suwan 2, Satha, Monghy, Tiniguib, Mimies, D771, SS2, Changez, Mian Taj-1, Farm Sumeri, BS10, Indian Pool 6, 8, 3 and 6, Minn. Syn. B, G and D, Sarhad
28	Nicaragua 55, Burdek, Sarhad, Changez, Monghy, Tiniguib, Satha, D771, Mian Taj 1, D741, Indian Pool 6, 8 and 3, Minn. Syn. B,G and D
29	D771, India P7 and P3, BS3, B4, B5, B10, BS13, Suwan 2, AICDSC7, Minn. Syn. 13 and 14, ETO AM, Warangal local, Pool 17, Buland Shahar local, Furrukkhabad local, FR Mo17, J663, Comp. Sel. Precoz, PR7535, Syn. 550
30	FR Mo17, FRB73, D741, H98, Suwan 2, Sarhad, H99, A670, FR632, J603, Ia. SSSE VI, FR619, B76, H51, FR4 A, H100, Pool 17, B79, B57, BS13, BS10, AICD SC7, RDBDDE, Penn. Sta. Syn. 2, PR7535, MSP1, CSP, MSP2, Yugoslavia Hyb. F2, Yugoslavia line
31	D742, Suwan 1 W, Phil. DMR2, SS2, Indian Pool 3 and 4, CM600, PK Across W, Pakelo, Biasa, Tiniguib, Menado Putili, Sarhad, Dholi 7722, D772, CM400, CM300, MSI, Soan, Mandi W, Changez, Delhi 7535, BS10, BS13, BS16, BS11, BSSS (R) C8, Pool 33, J603, Pool 17
32	Arg. 307, Katumani Comp. A and B, Across 7442, Suwan 1 W, Khahil, OB7442, Indian Pool 4, Mo14 W, Mo1 W, FRK 55, CI66, FR804 W, FR805 W, Changez, Early DMR2, Farm Sumeri, Yuzpsc 71C, TC1, Medok, IP8, SS8, JBS, Sarhad, Early DMR2, IP3, Tuxp. C17, ETO LT, Syn. PK, Mian Taj 2, D742, Soan
33	Suwan 1, Pool 29, Pool 17, Sarhad, J603, Suwan 2, J663, BS10, BS13, FR14 A, B76, B73, H101, Mo17, Iowa 2 ear H.O., Am. Bajio, BS11, L4, CSP, D741, B23, IP5, Syn. 551, Sarhad, N28, BSL (S) C4, Phil. Early DMR Comp. 1
34	Cornell materials, H98, FRB71, Suwan 1, A670, Sarhad, B79, FR Mo17, J603, Suwan 2, D741, Pool 17, J54, B23, Jahangirabad local, Pioneer X 440, B68, B57, BS10, BS13, Am. Bajio, L4, Pool 29, MSP2, PR7535, RN28 Ht Ht rhm rhm, RB37 Ht Ht rhm rhm, RB73 Ht Ht rhm rhm, B1138 T
STR	J603, Sarhad, Comp. Sel. Precoz, Ia. SSE, BS10, CSP, FR4 A, H100, Syn. 551, VL42, L4, Suwan 2, Pioneer X 440, B68, Suwan 1, FR Mo17, D741, Pool 29, IP3, BS13, ETO (M), AICDS (C7), H95, H96, H51, H670, Pool 17, B SSSS (R)

Table 3a. Performance of the various groups of families in Pool 20 after inoculation with ear rot[a/]

Ear rot (%/o rotten kernels)		Yield (kg/ha)		Plant height (cm)		Days to silk	
Poza Rica, summer 1980							
rrr[a/]	61.6	Rrr	3844	rRr	183	C1	53.2
RrR	51.8	RrR	3842	rrR	180	C3	53.1
Rrr	51.4	rrr	3818	C2	177	RrR	52.3
C3	49.8	RRr	3759	rRR	176	rRR	52.3
RRR	47.6	C4	3617	C1	176	C2	52.3
rRr	47.1	rRR	3589	RRR	175	RRR	52.2
C2	46.6	rrR	3576	C4	173	RRr	52.2
C1	46.5	C3	3542	RRr	170	C4	52.1
rRR	45.8	RRR	3462	C3	167	rrR	52.0
rRr	45.6	C2	3445	rrr	166	Rrr	51.8
rrR	41.5	rRr	3387	RrR	161	rrr	51.3
C4	38.2	C1	3167	Rrr	158	rRr	50.8
Average:							
Inoculated varieties	47.8						
Uninoculated varieties	25.0						
Poza Rica, winter 1981							
C2	56.9	rrR	3637				
C1	55.6	rRR	3606				
rrr	55.0	C3	3517				
Rrr	44.0	RrR	3481				
C3	42.7	Rrr	3466	Non-significant		Non-significant	
rrR	42.0	rrr	3410				
RrR	40.5	RRR	3399				
RRr	39.5	rRr	3370				
rRr	39.5	C4	3353				
C4	38.9	C2	3296				
rRR	36.5	C1	3249				
RRR	34.8	RRr	2862				
Average:							
Inoculated varieties	45.0						
Uninoculated varieties	14.7						

Note: Average score for uninoculated varieties was significantly different (P = 0.05) from that of inoculated varieties

[a/] R = resistant, r = susceptible, C1 - C4 = cycles of selection

Table 3b. Performance of the various groups of families in Pool 22 after inoculation with stalk rot[a/]

Stalk rot[a/]		Yield (kg/ha)		Plant height (cm)		Days to silk	
Poza Rica, summer 1980							
rRr[b/]	4.12	rrr	5025	Rrr	205	RRR	54.0
RRr	4.08	RRr	5007	C2	200	rRr	53.6
Rrr	3.90	Rrr	4917	RRr	196	C1	53.6
C3	3.87	RRR	4751	C4	191	RrR	53.3
C2	3.79	C2	4738	rRr	188	rRR	53.3
rrr	3.77	C3	4699	rrR	188	C2	53.1
RrR	3.76	rRr	4664	rrr	187	rrr	52.7
C1	3.71	C3	4480	C3	186	C3	52.7
rrR	3.64	rRR	4450	rRR	185	Rrr	52.5
rRR	3.38	rrR	4259	C1	185	rrR	52.2
C4	3.23	RrR	4187	RrR	178	C4	52.1
RRR	2.97	C1	4147	RRR	175	RRr	51.1
Average:							
Inoculated varieties	3.88						
Uninoculated varieties	3.09						
Poza Rica, winter 1981							
C1	4.5	rrR	4441			C1	95
rrr	4.4	rRR	4307			rRr	95
C2	4.2	C4	4190			RrR	95
Rrr	4.1	RRr	4104			C4	94
C3	3.9	RrR	4091			RRR	93
C4	3.8	rRR	4071	Non-significant		rRR	93
RRR	3.7	RRR	4059			rrR	93
rRr	3.7	rrr	3978			C3	93
RrR	3.5	Rrr	3915			C2	92
rrR	3.5	C3	3900			Rrr	92
RRr	3.4	C2	3754			rrr	92
rRR	3.3	C1	3371			RRr	92
Average:							
Inoculated varieties	4.44						
Uninoculated varieties	3.29						

Note: Average score for uninoculated varieties was significantly different (P = 0.05) from that of inoculated varieties

[a/] 1 - 5 scale (1 = completely resistant, 5 = completely susceptible)
[b/] R = resistant, r = susceptible, C1 - C4 = cycles of selection

Table 3c. Performance of the various groups of families in Pool 23 after inoculation with stalk rot[a]

Stalk rot[a]		Yield (kg/ha)		Plant height (cm)		Days to silk	
Poza Rica, summer 1980							
C3[b]	4.3	rRr	4912	rRR	190	C1	54.8
RRr	4.3	Rrr	4745	Rrr	188	C3	54.6
C1	4.2	rRR	4716	C1	188	rRr	54.2
rrr	4.0	C2	4651	C2	188	C2	54.1
C3	4.0	rrr	4637	rRr	187	rRR	53.8
rrR	4.0	RRr	4582	RRR	186	RrR	53.7
rRr	3.9	RRR	4580	RrR	185	C4	53.7
Rrr	3.9	RrR	4552	C4	176	RRR	53.6
rRR	3.4	C1	4380	rrR	172	Rrr	53.5
RrR	3.4	rrR	4286	RRr	171	rrr	53.5
C4	3.1	C4	4201	rrr	170	rrR	53.2
RRR	2.7	C3	3688	C3	160	RRr	52.6
Average:							
Inoculated varieties	3.81						
Uninoculated varieties	3.00						
Poza Rica, winter 1981							
rrr	3.90	rRR	4271			RRR	94.0
Rrr	3.57	C3	4064			C3	94.0
C1	3.53	RrR	4052			RrR	94.0
C2	3.40	rrR	4051			rrR	94.0
rrR	3.30	rRr	3885			rRR	93.5
RRr	3.30	rrr	3713	Non-significant		C1	93.5
RRR	3.20	RRr	3691			C2	93.5
rRr	3.10	RRR	3672			rRr	93.0
rRR	3.00	Rrr	3655			C4	92.7
C4	3.02	C4	3601			RRr	92.0
C3	3.01	C1	3535			Rrr	92.0
RrR	2.80	C2	3494			rrr	92.0
Average:							
Inoculated varieties	3.61						
Uninoculated varieties	2.97						

Note: Average score for uninoculated varieties was significantly different (P = 0.05) from that of inoculated varieties

[a] 1 - 5 scale (1 = completely resistant, 5 = completely susceptible)
[b] R = resistant, r = susceptible, C1 - C4 = cycles of selection

Table 3d. Performance of the various groups of families in Pool 33 after inoculation with ear rot[a/]

Ear rot (%/o rotten kernels)		Yield (kg/ha)		Plant height (cm)	Days to silk	
Tlaltizapan, summer 1980						
Rrr[a/]	63.7	rrr	5530		C1	53.7
rrR	63.5	C2	5413		RRR	53.2
rrr	63.2	rRr	5351		Rrr	53.2
rRR	60.5	rRR	5182		rRR	53.2
C3	52.5	RRr	5115		C4	53.2
C2	52.1	rrR	5084	Non-significant	C2	53.0
C1	51.8	RrR	5074		RrR	52.7
RrR	51.7	Rrr	5010		rrr	52.7
RRR	50.6	C4	4915		C3	52.7
C4	50.4	C3	4540		rRr	52.2
RRr	48.5	RRR	4469		rrR	52.2
rRR	48.1	C1	4139		RRr	52.0
Average:						
Inoculated varieties	54.7					
Uninoculated varieties	13.9					
Tlaltizapan, winter1981						
rrr	59.0	C1	4810			
C1	56.0	C2	4335			
C2	48.4	Rrr	4275			
rrR	39.2	rrr	4198			
RrR	37.8	C4	3773			
Rrr	36.4	rRr	3635	Non-significant	Non-significant	
rRr	34.0	C3	3612			
rRR	33.6	RrR	3533			
RRr	33.4	rRR	3490			
RRR	31.2	RRR	3482			
C4	31.0	RRr	3271			
C3	25.4	rrR	3254			
Average:						
Inoculated varieties	38.8					
Uninoculated varieties	17.3					

Note: Average score for uninoculated varieties was significantly different (P = 0.05) from that of inoculated varieties

[a/] R = resistant, r = susceptible, C1 - C4 = cycles of selection

Table 4a. Preliminary Evaluation Trial 1 of seven tropical materials at twelve locations, Poza Rica (A and B season) Tlaltizapan, Mexico, La Maquina, Guatemala, Sakha, Egypt, Suwan, Thailand, Kwadaso, Ghana, Pirsabak, Pakistan, Sete Lagoas, Brazil, Pergamino, Argentina, Kamboinse, Upper Volta, and Ilonga, Tanzania

Material	Yield			Days to 50% silking			Ear height		
	t/ha	b	s_d^2	days	b	s_d^2	cm	b	s_d^2
TEWF (Pool 15)	4.46	0.97	0.02	60	1.03	1.96	101	0.91	1.19
TEWD (Pool 16)	4.62	1.10	0.04	60	0.97	0.09	101	1.00	26.20
TEYF (Pool 17)	4.27	0.94	0.04	60	0.99	0.33	102	0.86	20.08
Trop. Am. Crist.-2 (Pool 31)	4.65	0.99	0.17	58	0.91	2.34	91	1.33	12.65
TEYD (Pool 18)	4.41	1.11	0.06	60	1.07	1.46	102	0.98	7.72
Ant.-Rep. Dom. (Pop. 35)	4.60	1.01	0.02	61	1.03	1.33	94	1.07	31.80
Ant.-Rep. Dom.-Pairu-Indonesia	4.04	0.88	0.07	60	1.00	0.44	96	0.85	7.00
SE of one b		0.06			0.03			0.10	
% CV	7.49			2.58			5.62		
LSD (5%)	0.14			0.63			2.25		

Table 4b. Preliminary Evaluation Trial 2 of 28 medium and late-maturing tropical materials at nine locations, Tlatizapan, Mexico, La Maquina, Guatemala, Poza Rica, Mexico, Kwadaso, Ghana, Suwan, Thailand, Takfa, Thailand, Sete Lagoas, Brazil, Kisanga, Zaire, and Ilonga, Tanzania

Material	Yield			Days to 50% silking			Ear height		
	t/ha	b	s_d^2	days	b	s_d^2	cm	b	s_d^2
TIWF (Pool 19) C9	5.25	1.00	0.09	57	0.96	0.46	106	1.03	10.45
TLWF (Pool 23) C9	5.42	1.12	0.02	60	0.99	0.62	113	1.00	6.74
Bl. Crist.-1 (Pop. 23) C4	5.19	1.05	0.05	59	1.00	1.07	111	1.00	32.93
Mix.-1-Col.Gpo. 1-ETO C4	5.26	1.04	0.17	61	0.98	1.44	107	1.07	29.88
ETO Blanco (Pop. 32) C3	5.12	1.07	0.08	61	0.99	0.24	111	1.02	52.78
TIWF (DMR) C3	4.96	0.72	0.21	58	1.00	2.50	123	1.13	13.68
TIWF (Stunt R) C3	5.18	0.99	0.30	61	1.03	0.47	122	1.07	28.73
TIWD (Pool 20) C9	5.16	0.99	0.08	59	0.94	2.41	109	1.00	46.01
TLWD (Pool 24) C9	5.74	1.10	0.13	61	0.97	0.20	116	1.03	0.04
Tuxpeño-1 (Pop. 21) C3	5.87	1.11	0.03	61	1.02	0.04	109	0.78	33.84
Mez. Trop. Blanca (Pop. 22) C4	6.08	1.08	0.14	62	1.00	1.66	122	1.02	16.41
Tuxpeño Caribe (Pop. 29) C4	5.76	1.12	0.29	62	0.98	0.00	121	1.09	0.00
La Posta (Pop. 43) C4	6.23	1.00	0.16	63	1.07	2.43	138	1.16	7.03
Tuxpeño PB-C15	5.05	1.04	0.06	61	1.02	4.00	100	0.71	121.94
Tuxpeño PB-Drought Sel.	5.36	1.08	0.18	62	0.99	1.59	101	1.04	18.25
TLWD (DMR) C3	5.41	1.04	0.33	61	0.95	0.00	126	1.03	28.95
TLWD (Stunt R) C3	5.21	1.02	0.01	62	1.07	0.08	128	0.93	0.07
TIYF (Pool 21) C9	5.44	0.99	0.04	58	0.96	1.55	115	0.93	3.36
TLYF (Pool 25) C9	5.23	0.86	0.08	60	1.02	0.83	118	1.03	10.31
Mez. Amar. (Pop. 26) C3	4.96	0.93	0.04	59	1.00	1.00	110	0.96	9.16

Table 4b. (Cont'd)

Material	Yield t/ha	Yield b	Yield s_d^2	Days to 50% silking days	Days to 50% silking b	Days to 50% silking s_d^2	Ear height cm	Ear height b	Ear height s_d^2
Am. Cristalino (Pop. 27) C4	5.12	1.02	0.29	62	1.04	0.87	122	1.08	9.04
TIYD (Pool 22) C10	5.30	0.87	0.04	60	0.99	0.45	112	1.02	18.10
TLYD (Pool 26) C9	5.40	1.09	0.08	60	1.01	0.45	117	0.93	9.84
Ant.-Ver. 181 (Pop. 24) C4	5.16	0.95	0.11	62	1.03	0.51	120	0.99	15.38
Am. Dentado (Pop. 28) C3	5.77	1.15	0.28	62	0.99	0.00	132	0.98	50.04
Cogollero (Pop. 36) C3	5.21	0.89	0.17	61	1.02	0.10	132	1.06	9.59
TYFD (DMR) C3	5.46	0.83	0.10	60	0.98	0.40	128	1.03	3.13
TYFD (Stunt R) C3	4.85	0.85	0.02	61	1.00	0.28	125	0.85	35.95
SE of one b		0.09			0.03			0.10	
% CV	8.08			1.82			4.64		
LSD (5%)	0.20			0.52			2.56		

Table 4c. Preliminary Evaluation Trial 3 of 15 subtropical and temperate materials at ten locations, Tlaltizapan, Mexico (A season) Sakha, Egypt, Suwan, Thailand, Pirsabak, Pakistan, Kisanga, Zaire, La Platina, Chile, Kamboinse, Upper Volta, Iboperenda, Bolivia, Lyamungu, Tanzania, and Tlaltizapan (B season)

Material	Yield t/ha	Yield b	Yield s_d^2	Days to 50% silking days	Days to 50% silking b	Days to 50% silking s_d^2	Ear height cm	Ear height b	Ear height s_d^2
SEWF (Poo 27) C9	4.59	0.73	0.23	58	0.97	0.29	90	0.84	23.52
SEWD (Pool 28) C4	4.90	0.90	0.08	58	0.90	2.64	87	0.73	43.07
SEYF (Pool 29) C5	4.42	0.84	0.22	57	0.85	0.86	89	0.86	55.55
SEYD (Pool 30) C5	4.51	0.93	0.60	56	0.88	1.45	82	0.79	3.26
Hungarian Composite (Pop. 48)	4.91	1.02	0.25	59	0.93	2.80	92	0.91	16.44
Indonesia - Corn Belt	5.23	0.91	0.16	61	1.01	5.00	107	1.02	29.62
Hungarian Composite (Pop. 48)	6.09	1.01	0.01	65	1.11	1.90	107	1.02	22.96
Blanco Subtropical (Pop. 34) C3	6.83	1.16	0.46	68	1.11	0.75	130	1.13	14.40
SIWD (Pool 32) C9	6.15	1.13	0.42	66	1.12	2.03	103	1.18	28.52
SIYF (Pool 33) C9	5.84	1.03	0.08	62	0.98	0.11	103	1.05	21.84
SIYD (Pool 34) C9	5.83	1.12	0.16	63	0.98	0.00	100	1.02	5.96
Amarillo Bajio (Pop. 45)	6.22	1.10	0.30	63	0.99	1.39	105	1.12	33.34
Ant. Rep. Dom.-Corn Belt	6.18	1.02	0.00	63	0.98	4.41	108	1.14	59.30
Am. Bajio-templados	6.48	1.15	0.40	66	1.09	4.15	124	1.15	21.08
Planta Pequeña Mazorca Grande	5.68	0.97	0.41	67	1.12	1.33	113	1.05	127.98
SE for one b		0.09			0.05			0.09	
% CV	11.46			3.22			6.93		
LSD (5%)	0.28			0.89			3.16		

Population Improvement

The overall process of maize improvement at CIMMYT begins with the development and improvement of gene pools. Each pool has a corresponding advanced and more refined population. Families from improved gene pools, as well as other improved materials which have reached a stage of refinement such that national programs can benefit from their use, are added to the advanced populations which are subjected to recurrent selection with a higher selection intensity and international progeny testing. There are four major activities carried out in the Population Improvement Program:

- Improvement and refinement of populations with upgraded materials from the corresponding pools;
- Multilocation international testing of full-sib progenies of the populations for selection of superior, broadly adapted progenies, both for continued improvement of maize populations and for selection of superior families for the development of experimental varieties;
- International testing of superior experimental varieties, leading to their further refinement by national programs and/or release to farmers, and
- Seed increase of superior and elite varieties for supply to cooperators for continued testing within their programs and further seed increase.

International testing plays a major role in the selection and refinement of improved materials. This begins as soon as the populations are considered to be sufficiently advanced to be of value to the national programs. The cooperators within the national programs provide testing locations which comprise a full spectrum of the major tropical and subtropical ecological zones for which the germplasm is targeted. The results of progeny and variety evaluation in these various environments guide CIMMYT breeders in their choice of materials to be used for future cycles of selection, and also provide potentially useful varieties for cooperators around the world.

Some national programs utilize the materials in a hybrid program. Although CIMMYT's emphasis is on intrapopulation improvement with open-pollinated varieties as the end product, information is also collected and made available to national programs on the heterotic response among various populations for the development of hybrids.

Improvement Methodology

The full-sib family selection scheme is used for improvement of the advanced populations. In each population, 250 reciprocal full-sibs are developed and evaluated in international progeny testing trials (IPTTs), both in the northern and southern hemispheres. Approximately 80 to 100 of the best full-sib families are selected on the basis of across-location data for the next improvement cycle. Since the retrieval of data takes about one year, one cycle of selection is completed every two years. The intervening period between the two test cycles is utilized to improve the population for the most deficient traits.

CIMMYT entomologist splits the stalks of harvested maize to determine levels of insect damage and infestation

The steps involved in this population improvement program are shown in Figure 1. A selection intensity of 30 to 35 percent is used for each population. As the program evolves, the germplasm in these populations is improved by continued selection, by partial replacement through incorporation of outstanding half-sib families from pools, and/or by complete substitution of the population. New populations are created by using the best 200 to 300 half-sib families from the gene pools. The incorporation process normally includes the 1) development of full sibs, 2) evaluation in IPTTs of families tentatively designated for the population, and 3) selection of superior families for final incorporation into the respective population(s).[1/]

Population Improvement Work, 1980-81

During the 1980-81 period, 23 populations with normal grain type were improved. The names and numbers of these populations, cycle of improvement, special characters for which each population was being improved, and seasonal sequence of operations in their improvement are given in Tables 1, 2a, 2b and 3.

Based on trials to measure progress in the recurrent selection program, some populations which did not show reasonable progress, or which were not contributing superior materials to national

1/ For more details see Paliwal, R.L., and E.W. Sprague, 1981, Improving Adaptation and Yield Dependability in Maize in the Developing World and Vasal, S.K., A. Ortega and S. Pandey, 1982, CIMMYT's Maize Germplasm Management, Improvement, and Utilization Program, CIMMYT, Mexico.

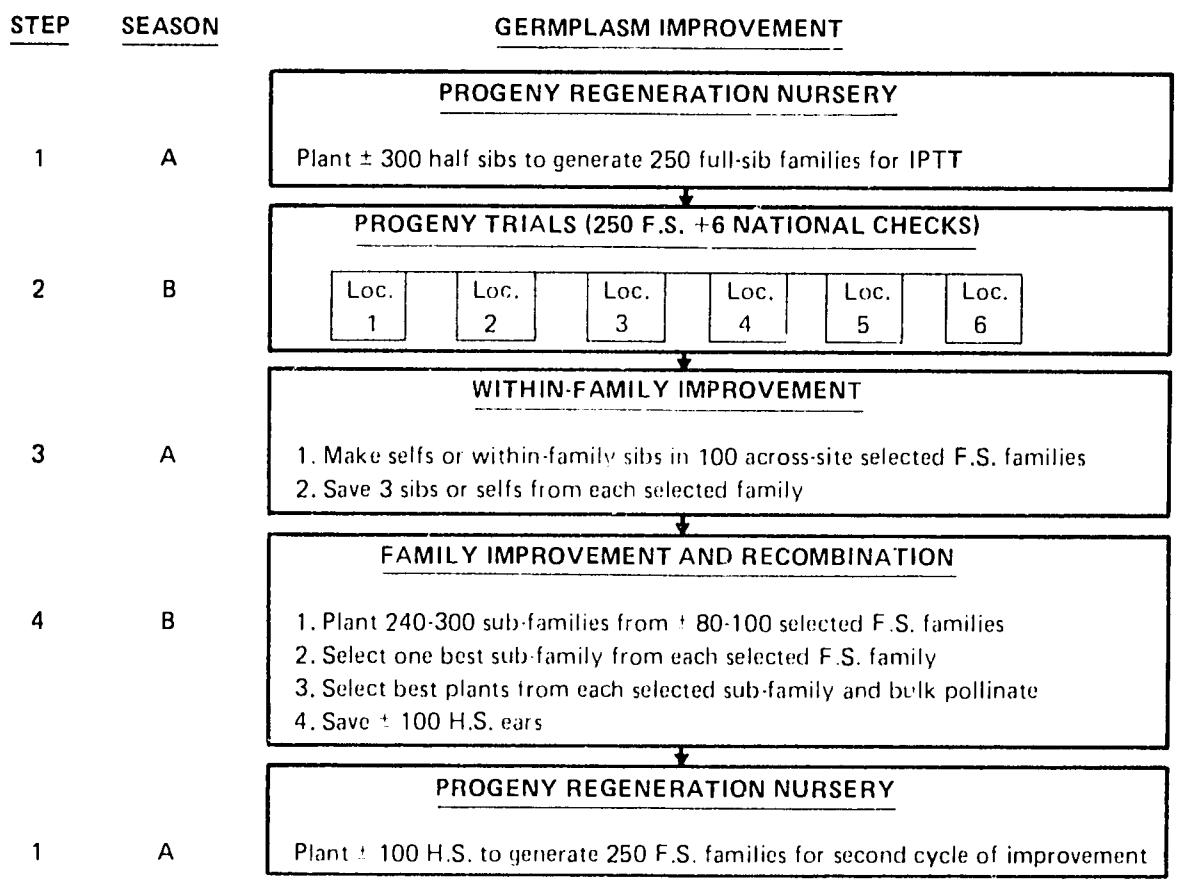


Figure 1. Population improvement breeding sequence scheme
Season A = CIMMYT's November-April crop breeding cycle; Season B = May-October crop breeding cycle
IPTT = international progeny testing trial

programs, were discontinued in 1980. Two populations, ETO-Illinois, (Pop. 42) and AEDX Tuxpeño (Pop. 44) were discontinued. Three new populations were developed and added to the population improvement program. They were:

- **Population 46** – Templado Amarillo Cristalino - with subtropical adaptation. Two hundred and forty half-sib families from the fourth cycle of selection of Gene Pool 29 were used to constitute this population;

- **Population 47** – Templado Blanco Dentado-2 - also for subtropical adaptation. Two hundred and seventy-six half-sib families from the eighth cycle of Gene Pool 32 were used to constitute this population, and

- **Population 49** – Blanco Dentado-2 - for tropical adaptation. It was constituted from 240 full-sib families from cycle 17 of Tuxpeño Crema-1 and is being improved in Mexico for shorter plant type and better grain efficiency.

Populations being improved for protein quality through incorporation of the O_2 gene and superior modifiers to produce kernels with hard endosperm, which were referred to earlier as HEO_2 (hard endosperm opaque-2), are now called quality protein maize (QPM) populations. All QPM materials are handled by a separate unit and are reported in another section of this report.

Climatic adaptation, maturity, seed color, and texture are considered to assemble populations. Each population underwent recurrent selection, using both among and within-family variation for a number of different traits, such as yield efficiency, maturity, and disease and insect resistance, according to the major crop production problems of the geographical areas for which it was intended. This convergent-divergent system of population improvement, drawing on a range of genetically diverse gene pools, relies heavily on extensive multilocational testing, and has resulted in the development of many broadly adapted and high-yielding maize materials for the tropics and subtropics.

Increasing grain yield efficiency

CIMMYT's improvement objectives have been to partition total dry matter toward more grain production, and to make tropical maize agronomically suitable to more intensive management, particularly the high-yielding, full-season materials. Selection for reduced plant height has helped to achieve both objectives.

Most CIMMYT maize populations now have generally acceptable plant height, yield potential, and standability. Many of these tropical lowland and subtropical populations, originally three to four meters tall, are now only about two meters tall or shorter. A few CIMMYT populations are still tall,

From an advanced CIMMYT population, 250 full-sibs are selected to form an international progeny testing trial, the first step in the distribution of this material to national research programs

and these are receiving selection pressure for reduced height. Several new populations have responded dramatically to such pressure. For example, Population 49, based on Tuxpeño Crema-1, is now less than two meters tall and has a grain-to-stover ratio near 50:50, roughly that of US Corn Belt materials.

Early maturity

In many tropical and subtropical areas, early-maturing varieties are desired, since they offer a number of potential benefits. In rainfed areas, for example, an early variety makes possible increased planting-date flexibility. In other areas, farmers may be able to increase their cropping intensity by using early-maturity maize varieties that can fit into their annual crop rotation system.

"Early" here means around 90 days to maturity. CIMMYT's Blanco Cristalino-2 (Pop. 30), a white semi-flint, lowland tropical material, is an example of an early-maturing population, as are Amarillo Cristalino-2 (Pop. 31), composed of early families from several yellow flint lowland tropical populations and crosses of tropical x temperate materials, and Templado Amarillo Cristalino (Pop. 46), a new, yellow flint, subtropical population. These early-maturing populations have been made available to national program collaborators through the international testing program.

Disease resistance

Susceptibility to disease is one of the important causes of yield instability, particularly in the hot and humid tropics. CIMMYT gives considerable emphasis to the development of reliable polygenic resistance (field resistance/tolerance) because of its contribution to yield stability. In the recurrent selection program in both pools and populations, selection pressure is exercised continuously for resistance to ear and stalk rots (using artificial inoculation techniques) and for leaf blights and rusts with natural incidence. Progeny trials grown at various locations provide the opportunity for selection of tolerant/resistant families in the environments where these materials will be used. Results of international trials show that the level of resistance to these foliar diseases has improved considerably in CIMMYT materials.

A collaborative program of disease research was initiated in 1974 to concentrate on germplasm resistance to three major diseases of maize in tropical areas, downy mildew, found throughout the humid tropics and subtropics and caused by different species of fungi in the genus *Peronosclerospora*, corn stunt disease, caused by Spiroplasma spp., widely distributed in the Americas and mainly transmitted by leafhoppers of the genus *Dalbulus*, and maize streak virus, found in tropical subequatorial Africa and transmitted mainly by leafhoppers of the genus *Cicadulina*. Six national maize programs entered this collaborative project, Thailand and the Philippines for downy mildew resistance, El Salvador and Nicaragua for corn stunt, and Tanzania and Zaire for maize streak.

In this research, CIMMYT and its collaborators followed a recurrent selection scheme, utilizing genetically broad-based maize populations which meet the grain type and maturity requirements of the national programs. Alternate cycles of selection were carried out in disease-prone areas in the collaborating countries to identify sources of resistance, and in Mexico to improve agronomic characters of the resistant selections.

Selection for resistance to these three diseases continued each year by planting at the time of highest disease incidence in the collaborating countries; each cycle of selection was followed by recombination of resistant families in Mexico. By 1980, good progress was noted in materials with resistance to downy mildew and corn stunt, and several resistant experimental varieties were developed.

Three broad-based tropical populations, tropical late white dent (TLWD), tropical yellow flint-dent (TYFD) and tropical intermediate white flint (TIWF), were improved for stunt and downy mildew resistance under this collaborative research project with national programs in Central America and Asia, and have shown good progress for resistance to these diseases (see 1978-79 Maize Report for details). In 1980-81, these populations were further improved for agronomic characters.

By 1980, four cycles of selection and recombination for downy mildew and corn stunt resistance had been completed; Table 4 presents the results of that work. Special trials using families of the resistant populations were then sent to collaborating countries. Yield trials were sent in 10 x 10 simple lattices with two replications, and were composed of 95 full-sib families and five local checks. Trials for corn stunt were planted in Guatemala, El Salvador, Nicaragua, Panama, the Dominican Republic, and Mexico. Trials for downy mildew were planted in Honduras, Venezuela, Nepal, Thailand, the Philippines, and Mexico.

Evidence shows that these selected families had good levels of disease resistance as well as good yield under both disease-free and disease-pressure situations. Other agronomic characters such as plant and ear height have been reduced, as well as days to flower.

Using information from these trials, 12 stunt-resistant experimental varieties were developed, and a variety trial was constituted and sent to 18 locations in Central America and Mexico. At most locations, the stunt-resistant varieties performed better than local checks included in the trials. Performance of some of these varieties is shown in Table 5. Particular mention should be made here of variety Santa Rosa 8043, which has shown outstanding performance at several locations. Similar trials with downy mildew-resistant varieties will be planted in 1982, and data for these trials will be available in 1983.

As this collaborative project and its benefits increased in importance, responsibility for selection and development of maize populations resistant to some diseases was transferred to the corresponding regional programs located in the affected areas. Three populations, Population 22, Mezcla Tropical Blanca, Population 28, Amarillo Dentado, and Population 31, Amarillo Cristalino-2, were handled in Thailand by the Asian Regional Program staff and improved specifically for downy mildew resistance, using CIMMYT's IPTT system. With this program, the regeneration of families was carried out at Farm Suwan to produce 250 reciprocal full-sib families in the late rainy season (planting in September) or under irrigation in the dry season (planting in November). Early in the following rainy season (planting in April or May), all of the 250 F.S. families were selfed, along with 30 to 50 downy mildew-resistant families from the so-called "side-car" (the equivalent of CIMMYT pools improved for downy mildew resistance). All of the families were improved under natural infestation. At harvest, one to three S_1 resistant ears per family were saved. Late in the rainy season, IPTT trials were conducted as part of multilocation testing.

Early in the rainy season of the following year, all of the S_1s were planted in a nursery under mild, uniform downy mildew pressure. Also, an additional nursery was planted with seed protected with Apron (Ridomil). Before flowering, IPTT data were available and 80 to 100 best families with their good S_1s were selected. The best one or two S_1 families, based on downy mildew resistance and good agronomic characteristics, were intercrossed. At harvest, 300 to 400 half-sib ears were saved for regeneration.

Late in the following rainy season, or in the dry season, all of the half-sib families were planted in two nurseries. In one nursery, the plants were sprayed with Ridomil (250 ppm) to prevent downy mildew infestation. In the other, the plants were inoculated with downy mildew spores on three consecutive evenings. In addition, 30 to 50 families from the respective "side-car" were planted. At flowering, approximately 1000 reciprocal crosses were made between the families of each group and, at harvest, about 200 families were selected from the normal population and 50 families from the "side-car" to get 250 full-sib families for use in the next cycle of improvement.

The advanced population La Posta (Pop. 43), which has given rise to very good varieties for several countries of Africa, is being handled by CIMMYT's West Africa Regional Program in cooperation with the International Institute of Tropical Agriculture (IITA) to improve its resistance to streak virus. The population continued to undergo recurrent selection for yield and other agronomic characters by international progeny testing, with emphasis on streak resistance through within-family improvement. Earlier work had shown that the natural incidence of streak virus was not reliable enough to make good selections, but IITA has developed reliable techniques for rearing African maize leafhoppers (*Cicadulina* spp.), vectors of the disease virus. Using artificial inoculation techniques, it has been possible to infect large numbers of families in tests for streak tolerance.

In 1980, 250 full-sib families from La Posta were infested in the greenhouse and evaluated for streak resistance. These plants were selfed and their progenies used in the next cycle of recombination of selected families. This recurrent selection scheme for streak resistance will continue to capitalize on the polygenic resistance present in the materials for several cycles. In addition to these efforts within La Posta, selected full-sib families of this population were crossed with a streak resistance source, TZSR-W-1, a full-season white population developed at IITA with good levels of resistance. These crosses were advanced to F_2 under streak pressure in 1981, and the F_2 generation was planted and screened for resistance or tolerance to the virus. The first backcross to the population La Posta was made by bulking pollen of selected plants and pollinating segregants highly tolerant to streak in the (La Posta x TZSR-W-1)F_2.

Experimental varieties from nine different advanced populations which have shown good performance in Africa, and which have a high level of resistance to most tropical diseases except streak, are undergoing conversion to streak resistance through backcrossing. The initial crosses with streak resistant donors were made in 1980. The best performing experimental variety from the latest cycle of each of these populations is used as recurrent parent. In this manner, the program takes advantage of the continuous progress being made in the recurrent selection of each of the parental populations. After each backcross, the BC_n-F_1 generation is advanced to BC_n-F_2 under artificial screening for streak resistance. Resistant segregants are used as female parents for the next backcross generation. Selection for desirable plant and grain type and maturity group of the recurrent parents is practiced in each generation. The breeding scheme is shown in Figure 2.

Insect resistance

Like disease, insect damage significantly reduces tropical and subtropical maize yields. Although appropriate insecticides exist, they may be unavailable in the developing world or, if available, beyond the financial means of many farmers. Therefore, breeding for resistance to insects is also a major CIMMYT research objective.

In Mexico, increased resistance is being sought by artificially infesting different populations with larvae of the fall armyworm, corn earworm, Southwestern corn borer, and sugarcane borer. These are the worst maize pests in the western hemisphere and are related to species causing serious damage on other continents.

Tuxpeño (Pop. 21) and Antigua-Veracruz 181 (Pop. 24), both lowland tropical materials, are being improved for resistance to fall armyworm (*Spodoptera frugiperda*). Similarly, two other

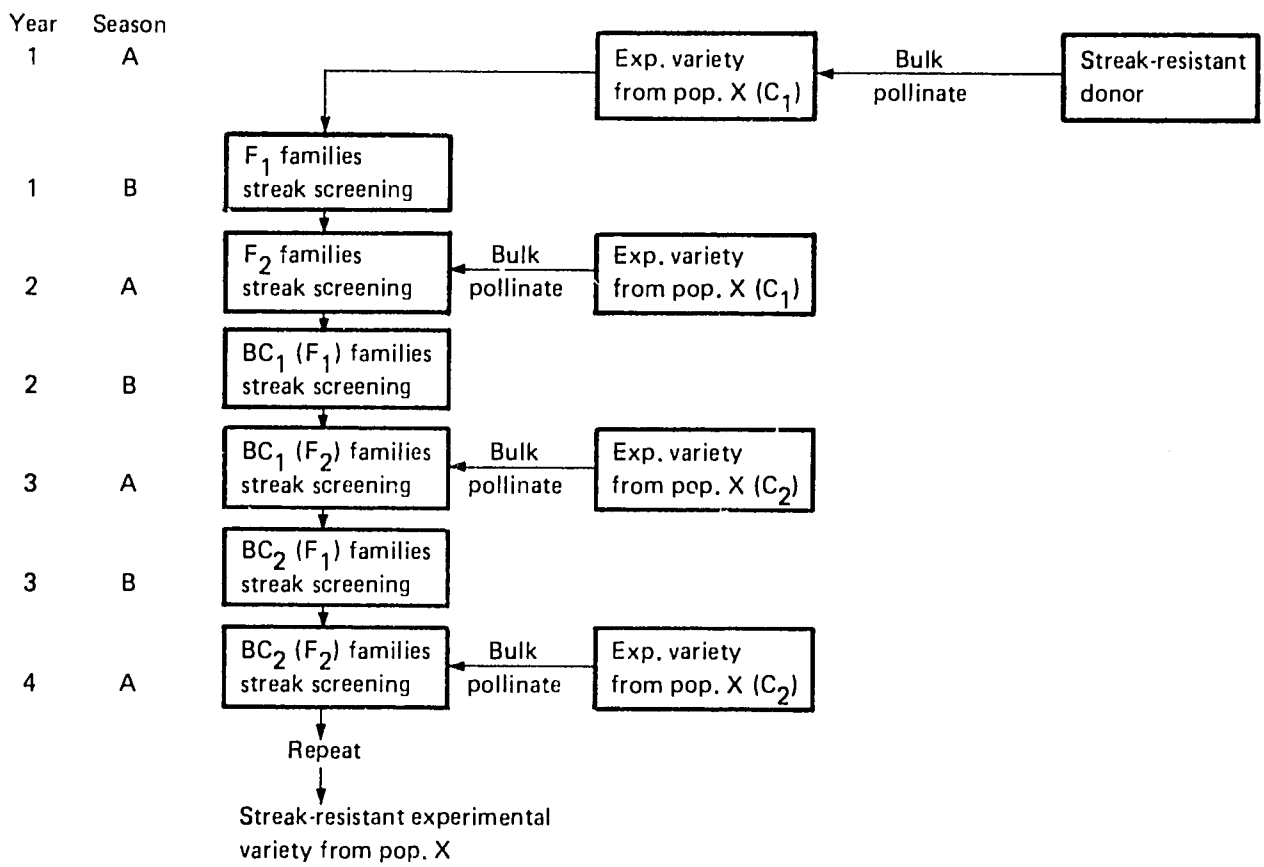


Figure 2. Scheme for converting experimental varieties from advanced unit populations undergoing improvement for streak resistance
Season A = CIMMYT's November-April crop breeding cycle; Season B = CIMMYT's May-October crop breeding cycle

tropical lowland populations, Amarillo Cristalino-1 (Pop. 27) and Blanco Cristalino-1 (Pop. 23) are being improved for resistance to the sugarcane borer (*Diatraea saccharalis*). One subtropical population, Templado Blanco Dentado-2 (Pop. 47), is being improved for resistance to the Southwestern corn borer (*Diatraea grandiosella*). Visual ratings for insect damage are made at different growth stages after artificial infestation, and progenies showing least damage are kept for recombination and use in future improvement cycles.

In addition to the efforts of improving host plant resistance in the selected CIMMYT maize populations, some small projects to attempt to screen for multiple resistance to maize stem borers were conducted in 1980-81 in collaborative efforts with Cornell University, the Turkish National Maize Program and the International Center for Insect Physiology and Ecology (ICIPE). Eighty-six families of maize selected for resistance to *Ostrinia nubilalis* at Cornell University were planted at CIMMYT and evaluated for resistance to Southwestern corn borers and sugarcane borer in 1980. Selections from the Cornell materials, along with apparently resistant S_2 selections from Populations 25 and 27, were sent upon request to ICIPE for screening for resistance to *Chilo partellus* in Kenya. From a total of 446 selections sent and screened, several lines were found to be more resistant to *Chilo partellus* than the local Kenyan cultivars (Omolo, 1983; Anon., 1983).

To assist the Turkish National Maize Program, where *Ostrinia nubilialis* and *Sesamia cretica* are potentially devastating pests of maize, twenty of the most promising lines for use in hybrid combinations in Turkey were screened for Southwestern corn borer resistance in 1981. Compared to the resistant checks (resistant selections from Cornell University and Mississippi), most were quite susceptible; therefore, resistant selections were made available to them for use in their breeding program.

A predoctoral student from Cornell University conducted studies at CIMMYT in 1980-81 to evaluate the potential for improvement and types of resistance to fall armyworm and the effectiveness of selection methods being used. Materials from Populations 21 and 24 were studied. Results indicated that 1) the screening method was able to identify genetic differences in fall armyworm resistance, 2) heritable variation for resistance was available in both materials and progress for resistance had been made with the current selection scheme, 3) the resistance available in Tuxpeño was primarily tolerance with low levels of antibiosis or nonpreference (the latter mechanisms were more important in Antigua-type materials), and 4) modifications to the selection/breeding scheme might allow for more rapid progress.

International Testing Activities

There are three stages in CIMMYT's international maize testing program—International Progeny Testing Trials (IPTTs), Experimental Variety Trials (EVTs), and Elite Variety Trials (ELVTs).

International Progeny Testing Trials

After three cycles of improvement in Mexico at two sites representing differing environments, populations enter into international progeny testing trials (IPTTs). Each population is tested every other year. CIMMYT selects 250 full-sib families from each of its advanced populations (only half of the populations are tested internationally each year) and sends seed for testing to collaborators at six sites worldwide, chosen on the basis of the suitability of the environment for the particular population in question. Each collaborator evaluates these 250 families in comparison with the best locally available hybrids or varieties (checks). From each progeny trial, the ten best-performing families (on the basis of yield potential, agronomic type, days to flowering, resistance to diseases and insects, and absence of lodging and rots) are, in most instances, chosen by national program staff and CIMMYT staff. At CIMMYT's stations in Mexico, the ten best entries from each test location are used to create an experimental variety, using remnant seed and intercrossing the ten families in all possible combinations.

The recombined seed of this family intermating is then bulked to produce an experimental variety identified by the site, year, and population, e.g., "Ferke 7928" refers to the ten best families selected from Population 28 grown at a 1979 IPTT location at Ferke, Ivory Coast. The IPTT data for a particular population are also used to identify the ten best-performing families across all six testing locations; such experimental varieties have the nomenclature "Across," e.g., Across 7928. Approximately 25 to 30 percent of the best families selected on the basis of across-site data are used to reconstitute the population for the next cycle of improvement. The F_1 of each experimental variety has to be increased (and advanced to the F_2) in order to have sufficient seed for testing at both levels, experimental variety and elite experimental variety, and to dissipate any heterotic effects generated during the formation of the variety.

The advanced populations are improved for three seasons at CIMMYT stations in Mexico before sending full-sib progenies for testing in international progeny trials. Information on IPTTs sent out in 1980 and 1981 is given in Tables 6 and 7. In 1980, a total of 66 IPTTs developed from 11 populations were distributed to cooperators in 28 countries; in 1981 a total of 67 IPTTs developed from 12 populations were sent to cooperators in 27 countries. In 1980, data was received from 73 percent of the trials while, in 1981, the percentage of IPTT data received was 64 percent.

Experimental Variety Trials

The experimental varieties from each advanced population created through this process are then assembled into experimental variety trials (EVTs) which are widely tested the following year in 30 to 70 locations throughout the developing world. In each of these testing locations, cooperators evaluate the experimental varieties against their best locally available check varieties and hybrids.

In 1980-81, a total of 154 new experimental varieties were developed and, in addition, 326 experimental varieties were advanced from F_1 to F_2 generations to minimize heterotic effects and provide adequate seed quantities for variety evaluation in experimental variety trials. The scheme used to form the varieties and later advance F_1 generation to F_2 is shown in Figure 3.

Elite Variety Trials

The best-performing experimental varieties across the 30 to 70 EVT locations are later assembled into elite variety trials (ELVTs) which are again distributed widely throughout the developing world on a national program request basis.

This international maize-testing system, with national program staff acting as full research partners, continues to grow in size and improve in precision. As national programs develop their own sets of gene pools and advanced populations, they also improve their capacity to utilize CIMMYT's array of germplasm in more effective ways to meet the varietal requirements of their local farmers.

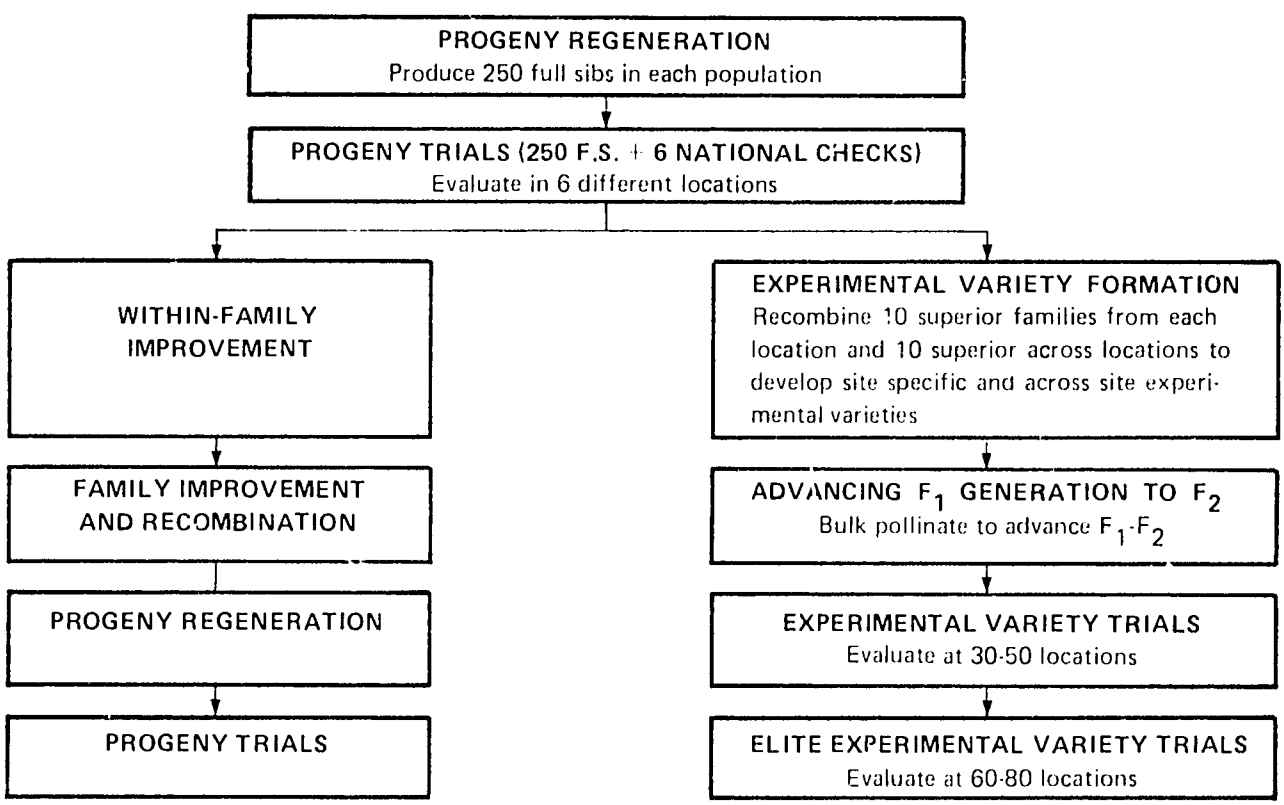


Figure 3. Steps in population improvement and experimental variety development and evaluation

The population improvement program at CIMMYT is essentially based on this testing by cooperators; the quality of the trials and data is vital for the success of the improvement program. An analysis was made of the quality of data received from IPTTs, and a summary is provided in Table 8 which gives the distribution of coefficients of variation (CV) and relative efficiency (RE) of the lattice design over that of a randomized block design. CVs of 20 percent or less are considered good, with CVs of 10 percent or less considered excellent; CVs of 21 to 25 percent are considered acceptable. An RE of 100 indicates that the statistical value of the lattice design is the same as that of a randomized block design, while values greater than 100 indicate that the lattice design is more efficient. REs of 125 or greater indicate that the lattice design is of significant benefit.

Table 8 shows that 39 of the 50 sets of data were good or excellent, as judged by the CV, and that eight of the data sets were considered acceptable. EVs were developed based on data of all of these trials. Only one EV was based on data from a trial with a CV in the 26 to 30 percent range, and no EVs were selected using data for the two trials that had CVs in the 31 to 35 percent range. However, in each case, an EV based on visual selection was requested by the cooperator. The use of the lattice design was of significant value in at least 15 of the locations, as judged by the values of the REs.

Another basis for evaluating the quality of the trials is the average yield achieved. The average trial yields (t/ha) are presented in Figure 4. Thirty-four of the trials achieved yields of 5 ha or higher. The fact that two-thirds of the trials attained such high yield levels is a tribute to the superiority of the germplasm and to the excellent management provided by the cooperators.

As of April 15, 1982, data from a total of 18 EVTs, 41 QPMTs, and 111 ELVTs had been received. The return rates were 43, 25, and 30 percent, respectively. Experimental variety trials 12 through 16 were not produced and distributed in 1981, as a result of a program decision to use only advanced generation seed (F_2) for variety trials; one additional season is required to produce F_2 seed. No interruption occurred in the ELVTs, as they have always been prepared using F_2 seed. As reported in the 1978-79 CIMMYT Report on Maize Improvement, the yield performance of an EV is 7 percent less, on average, when variety evaluation is made using advanced generation seed (F_2), as compared to the initial cross seed (F_1). The performance of the EVs using F_2 seed represents the actual varietal performance, since advancing seed to the F_2 generation establishes genetic equilibrium by eliminating any specific combining-ability effects present in the F_1 seed.

Various EVTs and ELVTs constituted in 1980 and 1981 and the numbers of each sent for international testing are given in Table 9. Two types of check varieties were included in each trial for comparison. A system of reference entries (REs) was introduced to serve as common and long-term checks in various EVTs and ELVTs. Elite varieties, which had demonstrated high and stable yield and reasonably wide adaptation in previous tests, were carefully chosen as reference entries. A second category of checks were local checks that were provided by individual cooperators, representing the best local varieties available for comparison.

A comparison of local checks with EVs indicates the performance of new materials for possible use by national programs; it also provides an indication of the breadth of a variety's adaptation. Comparisons of EVs with the best reference entries (which is the common check entry over all locations) provides an indication of whether the latest set of EVs is equivalent to or better than earlier-tested CIMMYT materials.

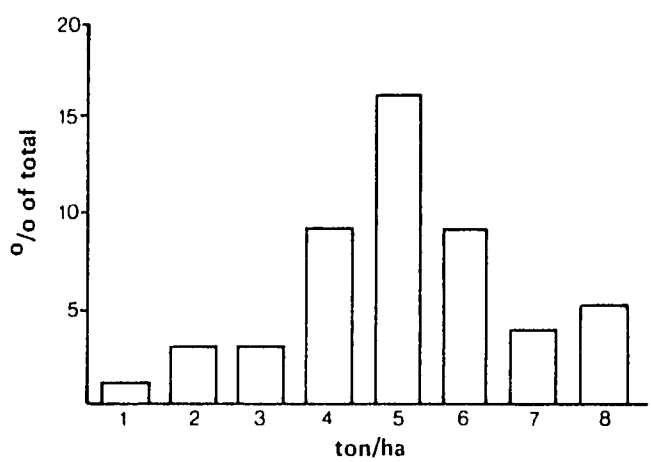


Figure 4. Distribution of mean yields (kg/ha) for the 1981 International Progeny Testing Trials (IPTTs)

An overall summary of varietal performance during 1981 is provided by the histograms in Figures 5 and 6. The category of 3 to 5 t/ha (Figure 6) contained the greatest percentage of sites for each of the six trials. Two trials, ELVT 18A and ELVT 20, were particularly noteworthy. Each trial had more than 20 percent of the total locations in the 6 t/ha or above category. ELVT 20 was grown primarily in subtropical or highland tropical areas, where moisture and temperature are less likely to be significant constraints to high yields than in the lowland tropical areas where ELVT 18A was principally grown.

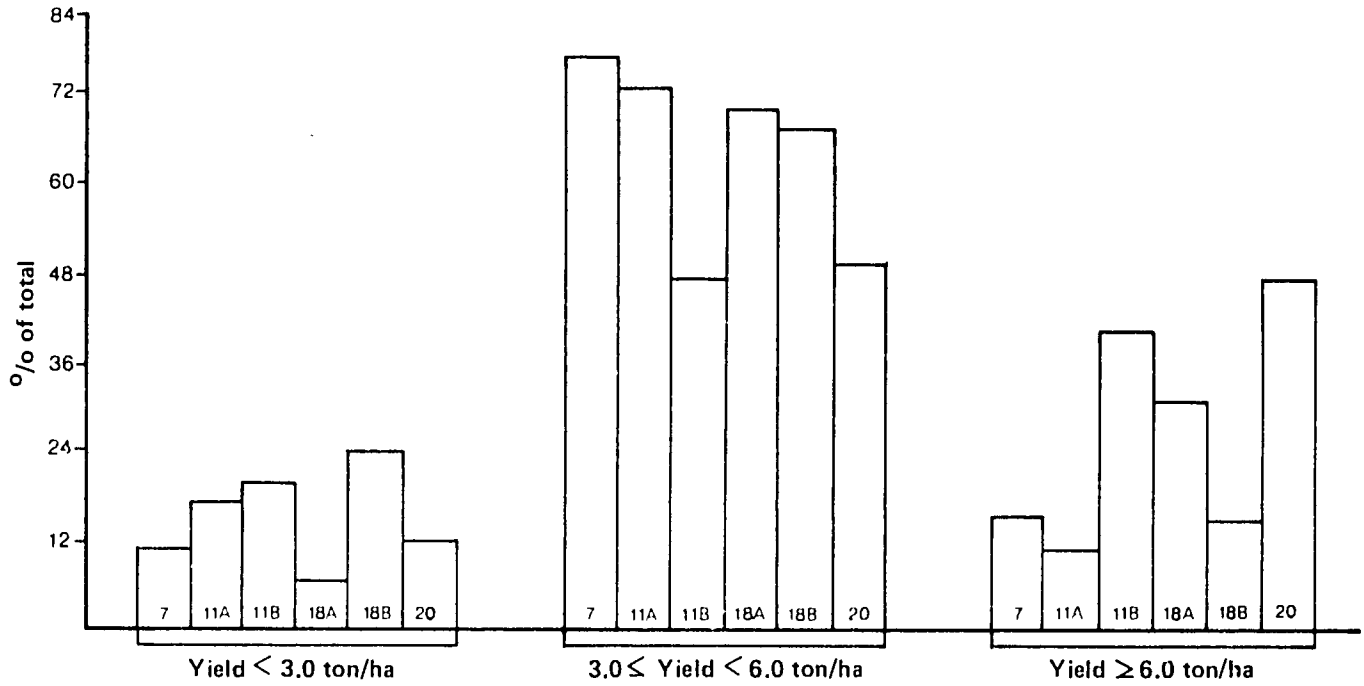


Figure 5. Histogram of mean yields for 1981 international variety trials

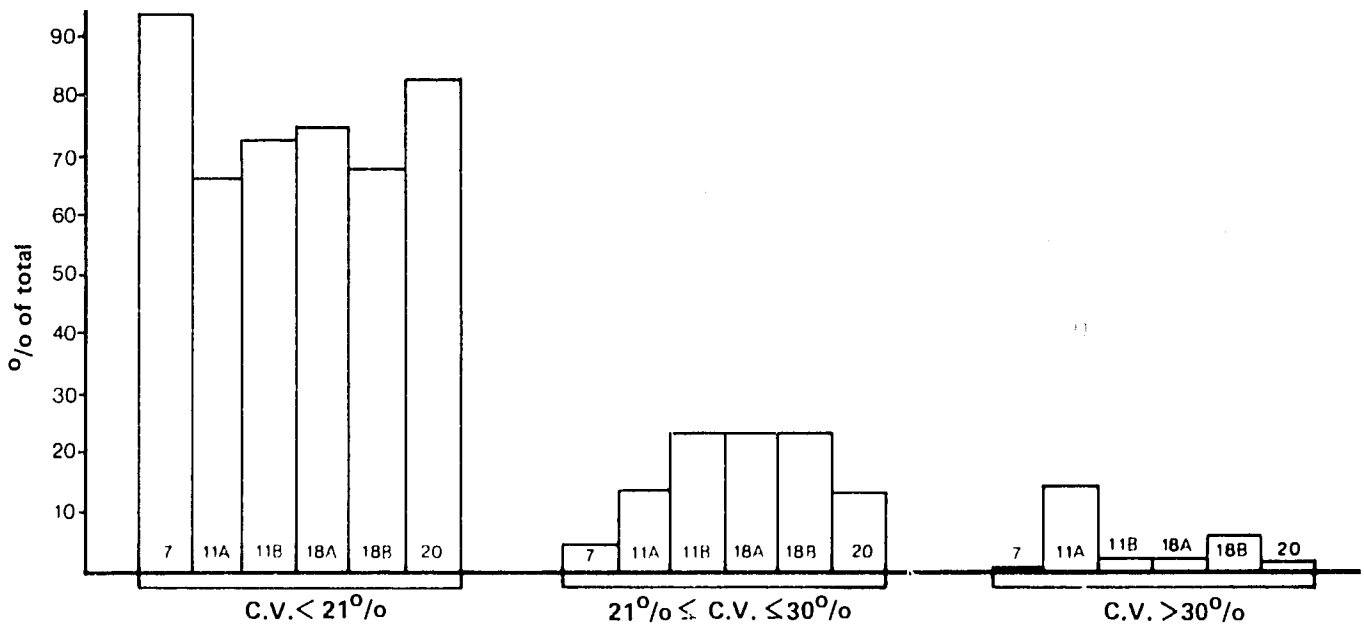


Figure 6. Histogram of coefficients of variation for the 1981 international variety trials

Some superior and elite varieties identified in 1980-81 are listed in Tables 10 to 14. Among white dent varieties, Across 7822, Poza Rica 7822, La Maquina 7843 and Across 7843 gave top performance in a number of locations in Asia, South America, and Africa. Among yellow dent varieties, Ferke (1) 7928 and Ferke 7928 were the top yielders; these were full-season varieties. Among medium and early-maturing varieties, Tocumen (1) 7926, Pirsabak (1) 7930 and Jutiapa (1) 7930 gave stable and high yield performance across several locations and, in addition, were earlier in maturity and shorter in plant height than the best checks. Among the subtropical varieties, Across 7842, Across 7844 and Cotaxtla 7844 gave consistently high yield and were also earlier in maturity and shorter in plant height than the best checks at several locations.

Table 15 shows a comparison of later-cycle experimental varieties (EVs) with the reference entries (REs) originating from the same population. Except for the EVs from population 29, all others of the later cycles outperformed the REs of the tested populations. This general trend is particularly encouraging, because of the fact that the REs are chosen from Across varieties which are based on stable, high-yielding, full sibs from all IPTT testing sites; the comparisions are based on EVs after one cycle of improvement.

Description of CIMMYT Maize Populations

Following is a description of CIMMYT's maize populations and the introgression of new germplasm into these populations. No tabular data are presented about the performance of populations for program selection, either of EVTs or ELVTs, since this information has been published in CIMMYT's Maize International Testing Reports for 1980 and 1981.

Population 21: Tuxpeño-1
Components: Tuxpeño race collections Veracruz 48, Veracruz 143, Veracruz 174, Michoacan 137, Michoacan 166, V-520C, Colima group 1-Mix.1, and 16 families from the tropical late white dent pool (Pool 24).

Description: Tropical lowland with white dent grain, late maturity, excellent standability, and relatively short plant type. Fairly tolerant of most foliar diseases. Good performance in most tropical lowlands. Specifically being improved since 1977 for resistance to fall armyworm.

Countries where progeny tests have been conducted:

1974: (C_0) Egypt (Gemeiza), India (Pantnagar), Guatemala (Cuyuta), Mexico (Cotaxtla and Poza Rica).
1975: (C_1) Costa Rica (Guanacaste), Mexico (Poza Rica), Tanzania (Ilonga).
1977: (C_2) El Salvador (San Andres), Guatemala (La Maquina), Honduras (Guaymas), Mexico (Poza Rica), Tanzania (Ilonga), Zaire (Gandajika).
1979: (C_3) Costa Rica (Los Diamantes), Mexico (Cotaxtla and Poza Rica), Venezuela (Maracay).
1981: (C_4) Brazil (Jardinopolis), Honduras (Omonita), Mexico (Poza Rica), Republic of South Africa (Potchefstroom), Zimbabwe (Rattray Arnold).

Population 22: Mezcla Tropical Blanco
Components: Tuxpeño, ETO blanco (Experimental Tulio Ospina, Medellin, Colombia), Antigua group 2 white selection, (Mix.1-Colima group 1)-ETO, Pfister hybrids, Compuesto Centro Americano, Lineas de El Salvador, V-520C, Nicarillo selecciòn blanca, and 13 families from the tropical late white dent pool (Pool 24).

Description: Tropical lowland, tropical with white dent-semident grain, late maturity. Very broad genetic base with tested good performance in the tropical regions of Mexico, Central America, northern South America, East and West Africa, and India. Since 1980, it has been subjected to selection for downy mildew resistance by CIMMYT's Asian Maize Regional Program in cooperation with Thailand's National Program at Kasetsart University, Suwan Station.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia (Palmira), Guatemala (La Maquina), Mexico (Poza Rica).
1975: (C_1) Colombia (Palmira), Honduras (Guaymas), Mexico (Poza Rica), Venezuela (Maracay).
1976: (C_2) El Salvador (San Andres), India (Delhi and Dheli), Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Philippines (Los Baños).
1978: (C_3) Bolivia (Chuquisaca), Mexico (Cotaxtla and Poza Rica), Tanzania (Ilonga).
1980: (C_4) Guatemala (La Maquina), Honduras (Guaymas), Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Nicaragua (Santa Rosa).

Population 23: Blanco Cristalino-1
Components: White segregates from Mezcla Amarilla, Antigua x Tipos Cubanos, Antigua x Cupurico, Poblacion Cristalina x Tuxpeño, Cuba 20, Granada 9D, CWF, Nicaragua syn. II, Harinoso de Ocho, and seven families from tropical late white flint pool (Pool 23).

Description: Tropical lowland with white semi-flint grain. Late to intermediate maturity, relatively short plant height. Less foliage than many tropical materials. Suitable for the lowland tropics of Mexico, Central America, northern South America, West Africa and Southeast Asia. Emphasis on sugarcane borer resistance.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia, (Palmira), El Salvador (San Andres), Mexico (Poza Rica), Nicaragua (Managua), Philippines (Los Baños).
1975: (C_1) Egypt (Gemeiza), Guatemala (Cuyuta), Mexico (Poza Rica), Pakistan (Pirsabak).
1976: (C_2) Colombia (Cali), Ghana (Nyankpala), Mexico (Cotaxtla and Poza Rica).
1978: (C_3) Colombia (Cali), Costa Rica (Los Diamantes), El Salvador (San Andres), Mexico (Poza Rica), Nicaragua (Santa Rosa).
1980: (C_4) Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Pakistan (Pirsabak), Venezuela (Maracay).

Population 24: Antigua-Veracruz 181
Components: Tuxpeño race collection Veracruz 181 and Antigua Group 2 (Antigua collections 1D to 8D).

Description: Lowland, tropical with yellow semi-dent grain. Intermediate plant height and maturity. Good performance in lowland tropics of South America, Central America, Mexico, Southeast Africa and Asia. Emphasis on improving resistance to fall armyworm.

Countries where progeny tests have been conducted:

1974: (C_0) Ecuador (Pichilingue), Mexico (Poza Rica), Pakistan (Patnagar), Thailand (Suwan).
1975: (C_1) Guatemala (Cuyuta), Mexico (Poza Rica and Obregon), Panama (Tocumen)
1976: (C_2) India (Dholi), Mexico (Poza Rica and Nayarit), Nicaragua (Santa Rosa), Pakistan (Yousafwala).
1978: (C_3) Brazil (Sete Lagoas), Costa Rica (Guanacaste), Ecuador (Pichilingue), Mexico (Poza Rica), Thailand (Suwan).
1980: (C_4) Mexico (Poza Rica), Panama (Chiriqui).

Population 26: Mezcla Amarilla
Components: Tuxpeño, Cuban flints, Antigua, ETO amarillo, some Corn Belt x Tuxpeño crosses, and 22 families from tropical intermediate yellow flint pool (Pool 21).

Description: Tropical lowland with yellow semi-flint grain, intermediate maturity, and relatively short plants. Composed basically of Caribbean germplasm. Good performance in the tropical lowlands of South America and parts of Asia. Emphasis on earliness and ear rot resistance.

Countries where progeny tests have been conducted:

1974: (C_0) India (Delhi), Mexico (Poza Rica), Nicaragua (Managua), Panama (Tocumen), Philippines (Los Baños).
1975: (C_1) India (Ludhiana), Ivory Coast (Ferkessedougou), Mexico (Poza Rica).
1977: (C_2) Bolivia (Chuquisaca), Brazil (Sete Lagoas and Petrolina), Ecuador (Pichilingue), Mexico (Poza Rica), Thailand (Suwan).
1979: (C_3) Bolivia (Saavedra), Mexico (Poza Rica), Pakistan (Islamabad), Panama (Tocumen), Peru (Piura).
1981: (C_4) India (Dharwad), Mexico (Poza Rica), Thailand (Suwan).

Population 27: Amarillo Cristalino-1
Components: Tuxpeño, Cuban flints, ETO amarillo, and 15 families from tropical late yellow flint pool (Pool 25).

Description: Tropical lowland with yellow flint grain. Intermediate plant size and medium to late maturity. Good performance in the lowland tropics of South America, the Caribbean area, India, and Southeast Asia. Being improved for borer resistance.

Countries where progeny tests have been conducted:

1974: (C_0) Guatemala (Cuyuta), India (Delhi), Mexico (Poza Rica and Obregon), Pakistan (Yousafwala), Panama (Tocumen).
1975: (C_1) Ecuador (Pichilingue), Mexico (Poza Rica), Nicaragua (Managua), Panama (Tocumen), Thailand (Suwan).
1976: (C_2) Colombia (Palmira), El Salvador (San Andres), Mexico (Poza Rica and Obregon), Peru (Satipo).

1978: (C_3) Costa Rica (Guanacaste), Ecuador (Pichilingue), Guatemala (La Maquina), Mexico (Poza Rica), Peru (Satipo).
1980: (C_4) Honduras (Guaymas), Mexico (Poza Rica), Panama (Tocumen), Thailand (Suwan).

Population 28: Amarillo Dentado
Components: Tuxpeño, Caribbean, Brazilian germplasm, ETO amarillo, and 9 families from tropical late yellow dent pool (Pool 26).

Description: Tropical lowland with late maturity, relatively tall plants, and yellow dent grain. High yields and tested good performance in the tropical lowlands of Mexico, Central America, South America, and parts of Asia. It has undergone four cycles of improvement through IPTTs, with special attention to plant-height reduction. Since 1980-81 it has been subjected to selection for downy mildew resistance by CIMMYT's Asian Regional Maize Program in cooperation with Thailand's National Program at Kasetsart University, Suwan Station.

Countries where progeny tests have been conducted:

1974: (C_0) Mexico (Poza Rica), Pakistan (Yousafwala), Panama (Tocumen).
1975: (C_1) Costa Rica (Guanacaste), El Salvador (San Andres), India (Ludhiana), Mexico (Poza Rica), Peru (San Ramon), Thailand (Suwan).
1977: (C_2) Bolivia (Chuquisaca), Brazil (Seto Lagoas), Mexico (Poza Rica), Nicaragua (La Calera), Panama (Tocumen).
1979: (C_3) Costa Rica (Guanacaste), Ecuador (Pichilingue), Guatemala (La Maquina), Ivory Coast (Ferkessedougou), Mexico (Poza Rica).
1981: (C_4) Ivory Coast (Ferkessedougou), Indonesia (Peobolingo), Panama (Guarare), Peru (La Molina), Thailand (Pak Chong).

Population 29: Tuxpeño Caribe
Components: Tuxpeño, Cuban flints, ETO.

Description: Tropical lowland with white dent grain and late maturity. High yield potential demonstrated in Mexico, Central America, Egypt, and parts of Africa and Asia. Emphasis on reduced plant height.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia (Palmira), Ecuador (Pichilingue), Guatemala (Cuyuta), Mexico (Cotaxtla and Poza Rica).
1975: (C_1) Honduras (Guaymas), Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Tanzania (Ilonga).
1977: (C_2) Costa Rica (Guanacaste), Mexico (Poza Rica), Tanzania (Ilonga), Zaire (Kisanga).
1979: (C_3) Egypt (Sids), Guatemala (Cuyuta), Honduras (El Paraiso), Mexico (Cotaxtla and Poza Rica).
1981: (C_4) Colombia (Palmira), Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Nicaragua (El Plantel).

Population 30: Blanco Cristalino-2
Components: Thirty-six families from "Selección compuesto precoz" C_8 (derived from the early fraction of all late tropical CIMMYT populations), crosses of tropical x temperate materials, and 49 families from tropical early white flint pool C_6 (Pool 15).

Description: Tropical and subtropical with early maturity and relatively short plants. To maximize yield potential, recommended plant density of 60,000 plants per ha. Emphasis on earliness and ear rot resistance.

Countries where progeny tests have been conducted:

1979: (C_0) Guatemala (Jutiapa), El Salvador (Santa Cruz Porrillo), Mexico (Poza Rica), Pakistan (Pirsabak), Tanzania (Ilonga).
1981: (C_0) Colombia (Palmira, CIAT), Honduras (Comayagua), India (Kolhapur), Mexico (Poza Rica).

Population 31: Amarillo Cristalino-2
Components: Ninety-six families from "Compuesto selección precoz" C_8 (derived from the early fraction of all late tropical CIMMYT populations), crosses of tropical x temperate materials, and four families from the tropical early yellow flint pool C_6 (Pool 17).

Description: Tropical and subtropical with yellow flint to semi-flint grain, early maturity, and relatively short plants. To maximize yield potential, recommended plant density about 60,000 plants per ha. Since 1980 subjected to selection for downy mildew resistance by CIMMYT's Asian Regional Maize Program in cooperation with Thailand's National Maize Program at Kasetsart University, Suwan Station.

Countries where progeny tests have been conducted:

1979: (C_0) Brazil (Sete Lagoas), Ecuador (Pichilingue), Mexico (Poza Rica), Panama (Tocumen), Peru (Satipo).
1981: (C_0) Ivory Coast (Bouake), Pakistan (Islamabad), Peru (La Molina), Thailand (Pak Chong).

Population 32: ETO Blanco
Components: Eleven ears selected in Colombia from advanced crosses of Colombia 1 (Blanco Comun, Blanco de Urrao) and Venezuela 1 (Cuban yellow flints) with recombined germplasm from Argentina, Brazil, Cuba, Mexico, Puerto Rico, USA, and Venezuela. The white segregates originated from ETO Blanco (or Diacol V-351).

Description: Subtropical with intermediate maturity. At CIMMYT its performance in the lowland tropics has been improved considerably. White hard flint grain type. Short plant type. Successfully grown in the Andean Region below 1500 m, parts of West Africa, Egypt, India, and Southeast Asia. Emphasis on ear rot resistance. Its excellent combining ability with Tuxpeño has long been recognized. This ETO variety has been distributed in Colombia since 1951.

Countries where progeny tests have been conducted:

1975: (C_0) Costa Rica (Alajuela), Mexico (Poza Rica and Obregon), Pakistan (Pirsabak), Venezuela (Maracay).
1976: (C_1) El Salvador (San Andres), Guatemala (Cuyuta), India (Pantnagar), Mexico (Poza Rica), Philippines (Los Baños).
1978: (C_2) Egypt (Sakha), Mexico (Poza Rica), Venezuela (Maracay), Zaire (Gandajika).
1980: (C_3) Costa Rica (Alajuela), Mexico (Cotaxtla and Poza Rica).

Population 33: Amarillo Subtropical
Components:Two hundred seventy-five half-sib families were selected from the eighth cycle of recurrent selection of Pool 33 (temperate intermediate yellow flint). Yellow segregates from crosses of germplasm from Mexico, US Corn Belt, Brazil, Uruguay, Argentina, China, Pakistan, Yugoslavia, Lebanon, Guatemala, Venezuela, Peru, Cuba, Antigua, and the Dominican Republic.

Description: New, genetically broad-based intermediate subtropical-temperate yellow flint, with medium to short plants. Emphasis on ear rot resistance.

Countries where progeny tests have been conducted:

1980: (C_0) Guatemala (San Jeronimo), India (Pantnagar), Mexico (Tlaltizapan), Pakistan (Yousafwala).

Population 34: Blanco Subtropical
Components: Palung Valley white, Synthetic 66, Pando, ETO blanco, Dwarf 1 tall, Población Cristalina, Tuxpeño Crema 1, Dwarf 1 short, PD(MS)6, Amarillo Peru, Sintetico de 10 lineas.

Description: Subtropical, broad genetic base including germplasm from Cuban flints, ETO, Tuxpeño, Corn Belt Dent, India, and Nepal. Late maturity, semi-dent grain, and relatively tall plants. High yield potential demonstrated in Pakistan, parts of India, South Brazil, and subtropical regions of Mexico. Has undergone four cycles of selection through the IPTT system, with emphasis on reduced plant height.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia (Palmira), Mexico (Obregon), Mexico (Tlaltizapan), Nepal (Rampur), Pakistan (Pirsabak).
1975: (C_1) Egypt (Sids), Mexico (Obregon and Tlaltizapan), Tanzania (Ukiriguru).
1977: (C_2) Egypt (Sids), India (Pantnagar), Mexico (Obregon and Tlaltizapan), Pakistan (Pirsabak), Tanzania (Hjombe).
1979: (C_3) Brazil (Sete Lagoas), Zaire (Kaniama), Mexico (Tlaltizapan).
1981: (C_4) Egypt (Skaha), Ethiopia (Nazareth), Guatemala (San Jeronimo), Mexico (Tlaltizapan), Tanzania (Lambo).

Population 35: Antigua-Republica Dominicana
Components: Republica Dominicana groups 2,3 7, 8, 9, and 15 crossed with Antigua Group 2 (Antigua collections 1D to 8D).

Description: Tropical lowland, intermediate in maturity, yellow dent grain type. Short type with tolerance to stunt. Is being improved for better stalk quality and standability. Performs well in Mexico, Central America, the Caribbean, and lowland tropical regions of South America, West Africa, parts of South Africa, Pakistan, India, and South East Africa.

Countries where progeny tests have been conducted:

1975: (C_0) Colombia (Turipana), Ecuador (Pichilingue), El Salvador (San Andres), India (Delhi), Mexico (Poza Rica), Thailand (Suwan).

1976: (C_1) Guatemala (La Maquina), India (Ludhiana), Ivory Coast (Ferkessedougou), Mexico (Poza Rica), Panama (Tocumen).
1978: (C_2) Brazil (Bahia), Ecuador (Pichilingue), El Salvador (Santa Cruz Porrillo), Haiti (Levy), Mexico (Poza Rica), Panama (Tocumen).
1980: (C_3) Mexico (Poza Rica), Pakistan (Islamabad), Thailand (Suwan).

Population 36: Cogollero
Components: Caribbean Composite involving 165 accessions from all the Caribbean islands. About 50 families from IDRN population, twenty families from Pool 22, and 26 families from Pool 26.

Description: Lowland tropical and subtropical, yellow semi-dent grain, intermediate to late maturity, tall plants. A broad genetic base derived from Caribbean Composite. New germplasm added from Pool 22 (tropical intermediate yellow dent) and Pool 26 (tropical late yellow dent). Good performance in Central America, lowland South America, and parts of Africa. Has been subjected to four cycles of improvement through IPTTs; reduction of plant height is given emphasis.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia (Palmira), Mexico (Poza Rica), Thailand (Suwan).
1975: (C_1) Ecuador (Pichilingue), Guatemala (Cuyuta), Mexico (Poza Rica), Panama (Tocumen), India (Chindwara).
1977: (C_2) Bolivia (Chuquisaca), Brazil (Petrolina), Mexico (Poza Rica and Tlaltizapan), Thailand (Suwan).
1979: (C_3) Mexico (Obregon and Poza Rica), Peru (Piura).
1981: (C_4) Brazil (Londrina), Mexico (Poza Rica), Philippines (V.P. Los Baños).

Population 42: ETO-Illinois
Components: Population 32 plus seven US Corn Belt inbred lines resistant to common rust (*Puccinia sorghi*) and 18 US Corn Belt lines resistant to turcicum leaf blight (*Helminthosporium turcicum*) used as differentials in worldwide evaluations.

Description: Advanced generation of short-plant selected ETO with Illinois stock. Segregated for resistance (major genes) to *P. sorghi* and *H. turcicum*. For subtropical to cooler areas. Emphasis on reduced plant height and uniformity for white grain. Has shown good performance in the highlands of Africa.

Countries where progeny tests have been conducted.

1974: (C_0) Egypt (Gemeiza), Mexico (Obregon), Pakistan (Pirsabak), Turkey (Adapazari).
1975: (C_1) Egypt (Sids), Mexico (Obregon and Tlaltizapan), Tanzania (Ukiriguru), Turkey (Adapazari).
1976: (C_2) Colombia (Cali), Mexico (Tlaltizapan), Nepal (Khumaltar), Pakistan (Pirsabak).
1978: (C_3) Bolivia (Chuquisaca), Brazil (Sao Paulo), Egypt (Sakha), Mexico (Tlaltizapan), Zaire (Kisanga).

Population 43: La Posta
Components: Tuxpeño synthetic composed of 16 inbred lines.

Description: Tropical lowland with white dent grain. Based on Tuxpeño germplasm. Tall and late with high yield potential, verified in lowlands of South America, Central America, Mexico, humid tropics of West and Central Africa, and parts of East Africa. Emphasis on streak resistance and reduced plant height in Nigeria IITA-CIMMYT cooperative program.

Countries where progeny tests have been conducted:

1974: (C_0) Colombia (Palmira), Egypt (Sids), Mexico (Obregon, Poza Rica and Tlaltizapan).
1975: (C_1) Mexico (Cotaxtla, Obregon and Poza Rica), Venezuela (Maracay).
1976: (C_2) Ghana (Nyankpala), Honduras (Omonita), Ivory Coast (Ferkessedougou), Mexico (Obregon and Poza Rica), Philippines (Los Baños).
1978: (C_3) Ghana (Ejura), Guatemala (La Maquina), Mexico (Poza Rica).
1980: (C_4) Costa Rica (Los Diamantes), El Salvador (San Andres), Mexico (Cotaxtla).

Population 44: AED (American Early Dent)-Tuxpeño
Components: American Early and Tuxpeño (see Population 21).

Description: Advanced generation of American Early (from Egypt) with short-plant Tuxpeño material. Fairly tall, late white dent. Capable of very high yields under favorable conditions. Has shown good performance in Egypt, Turkey, highlands of Africa, and as winter maize in India and Pakistan. Emphasis on reduced plant height.

Countries where progeny tests have been conducted:

1974: (C_0) Egypt (Sids), Mexico (Poza Rica and Tlaltizapan).
1975: (C_1) Egypt (Gemeiza), Mexico (Obregon and Tlaltizapan), Tanzania (Ukiriguru).
1976: (C_2) Egypt (Gemeiza and Sids), India (Dholi), Mexico (Tlaltizapan), Pakistan (Yousafwala).
1978: (C_3) Egypt (Gemeiza and Sids), Mexico (Cotaxtla and Tlaltizapan), Zaire (Kisanga).

Population 45: Amarillo Bajio
Components: Inbred lines from Purdue University, US13, Pfizer hybrids 347, 381, 383, 409 and 418, Hixanth., CBC Nebraska, Iowa stiff stalk synthetic, Tuxpeño, Cuban flints, Puerto Rico composite, collections from the Dominican Republic.

Description: Subtropical-temperate, intermediate maturity, yellow dent. Broad germplasm base derived from crosses among lowland tropical maize types from Mexico and the Caribbean and 45 US Corn Belt dents. Emphasis on reduced plant height.

Countries where progeny tests have been conducted:

1978: (C_0) Bolivia (Chuquisaca), Mexico (Tlaltizapan), Pakistan (Yousafwala).
1980: (C_1) Mexico (Obregon and Tlaltizapan), Turkey (Antalya).

Population 46: Templado Amarillo Cristalino
Components: Two hundred forty half-sib families from the fourth cycle of selection of Pool 29.

Description: New population, wide genetic base, early maturity, yellow flint grain, adapted to subtropical-temperate areas. Full-sib selection initiated and continued for four cycles to improve uniformity for plant type, maturity, and other characters. For maximum yield potential of this early short plant type population, plant density should be about 60,000 plants per ha. Emphasis on stalk rot resistance. Has shown good performance in Asia and South America.

Countries where progeny tests have been conducted:

1980: (C_0) Mexico (Obregon and Tlaltizapan)
1981: (C_1) Brazil (Capinopolis), India (Coimbatore), Mexico (Tlaltizapan), Pakistan (Pirsabak), Peru (La Molina).

Population 47: Templado blanco dentado-2
Components: Two hundred seventy-six half-sib families from the eighth cycle of selection of Pool 32.

Description: Temperate and subtropical white intermediate dent. Short plant type with high yield potential. Emphasis on Southwestern corn borer resistance. Has shown good performance in Asia and Africa.

Countries where progeny tests have been conducted:

1980: (C_0) Egypt (Gemeiza), Ethiopia (Awassa), Mexico (Tlaltizapan), Pakistan (Swat).

Population 48: Compuesto de Hungria
Components: Central US Corn Belt materials, southern European materials, 54 half-sib families from Pool 30.

Description: Yellow dent grain with early maturity. Good yield potential in temperate regions. Emphasis on resistance to leaf diseases and ear rot. Gives good performance in the Mideast around the Black Sea and as winter maize in other areas.

Countries where progeny tests have been conducted:

1974: (C_0) Mexico (Obregon), Pakistan (Pirsabak), Turkey (Adapazari and Samsun).
1975: (C_1) India (Dolhi), Iran (Karaj), Mexico (Tlaltizapan), Turkey (Samsun).
1977: (C_2) India (Dohli), Mexico (Obregon).
1979: (C_3) Chile (Quilampu), Mexico (Tlaltizapan), Turkey (Adapazari).

Population 49: Blanco dentado-2
Components: Initial selection of 240 full-sib families from Tuxpeño Crema-1 C_{17} (see Population 21).

Description: White dent grain, intermediate maturity, adapted to lowland tropical-subtropical areas. Through cycles of selection, plant height has been considerably reduced and the population made earlier compared to the genetically related population Tuxpeño 1 (Pop. 21). For maximum yield potential, recommended plant density about 60,000 plants per ha.

Countries where progeny tests have been conducted:

1980: (C_0) Mexico (Obregon and Poza Rica).
1981: (C_1) Mexico (Poza Rica), Nigeria (Ikene), Zaire (Gandajika), Zimbabwe (Rattray Arnold).

Table 1. CIMMYT maize populations, 1980-81

Group I (internationally tested in even years)		Group II (internationally tested in odd years)	
Pop. no.	Name	Pop. no.	Name
22	Mezcla Tropical Blanca	21	Tuxpeño-1
23	Blanco Cristalino-1	26	Mezcla Amarilla
24	Antigua-Veracruz 181	28	Amarillo Dentado
27	Amarillo Cristalino-1	29	Tuxpeño Caribe
32	ETO Blanco	30	Blanco Cristalino-2
33	Amarillo Subtropical	31	Amarillo Cristalino-2
35	Antigua-Rep. Dominica	34	Blanco Subtropical
39	Yellow QPM[a]	36	Cogollero
43	La Posta	40	White QPM[a]
45	Amarillo del Bajío	41	Templado Amarillo QPM[a]
47[b]	Templado Blanco Dentado	46[b]	Templado Amarillo Cristalino-3
		49[b]	Blanco Dentado-2

[a] QPM = quality protein maize (the old populations called HEO_2 (hard endosperm opaque-2) were renamed QPM in 1980)

[b] New populations

Table 2a. Seasonal sequence in the improvement of maize populations, Group I, 1980-81

Pop. no.	Selection emphasis	Location	Breeding procedures			
			1980A	1980B	1981A	1981B
22	Downy mildew resistance	Poza Rica, Farm Suwan	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
23	Sugarcane borer resistance	Poza Rica	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
24	Fall armyworm resistance	Poza Rica	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
27	Sugarcane borer resistance	Poza Rica	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
32	Ear rot resistance	Poza Rica	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
33	Ear rot resistance	Tlaltizapan	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
35	Standability	Poza Rica	Reciprocal Sibs	IPTT	Selfing	Recombination of S1s
39	Reduced plant height	Poza Rica	Reciprocal Sibs	IPTT	Within-family sibs	Recombination of Sibs

Table 2a. (Cont'd)

Pop. no.	Selection emphasis	Location	Breeding procedures			
			1980A	1980B	1981A	1981B
43	Streak resistance	Poza Rica, Ibadan	Reciprocal Sibs	IPTT	Within-family sibs	Recombination of Sibs
45	Reduced plant height	Tlaltizapan	Reciprocal Sibs	IPTT	Within-family sibs	Recombination of Sibs
47	Southwestern corn borer resistance	Tlaltizapan	Reciprocal Sibs	IPTT	Selfing	Recombination of Sibs

Table 2b. Seasonal sequence in the improvement of maize populations, Group II, 1980-81

Pop. no.	Selection emphasis	Location	Breeding procedures			
			1980A	1980B	1981A	1981B
21	Fall armyworm resistance	Poza Rica	Selfing	Recombine S1s	Reciprocal sibs	IPTT
26	Earliness and ear rot resistance	Poza Rica	Selfing	Recombine S1s	Reciprocal sibs	IPTT
28	Downy mildew resistance	Poza Rica, Farm Suwan	Selfing	Recombine S1s	Reciprocal sibs	IPTT
29	Reduced plant height	Poza Rica, Farm Suwan	Within-family sibs	Recombine sibs	Reciprocal sibs	IPTT
30	Husk cover and ear rot resistance	Poza Rica	Selfing	Recombine S1s	Reciprocal sibs	IPTT
31	Downy mildew resistance	Poza Rica, Farm Suwan	Selfing	Recombine S1s	Reciprocal sibs	IPTT
34	Reduced plant height	Tlaltizapan	Within family-sibs	Recombine sibs	Reciprocal sibs	IPTT
36	Reduced plant height	Poza Rica	Within-family sibs	Recombine sibs	Reciprocal sibs	IPTT
40	Reduced plant height and ear rot resistance	Poza Rica	Within-family sibs	Recombine sibs	Reciprocal sibs	IPTT
41	Husk cover and ear rot resistance	Tlaltizapan	Selfing	Recombine sibs	Reciprocal sibs	IPTT

Table 2b. (Cont'd)

Pop. no.	Selection emphasis	Location	Breeding procedures 1980A	1980B	1981A	1981B
46	Earliness and stalk rot resistance	Tlaltizapan	Among-family sibs	Recombine sibs	Reciprocal sibs	IPTT
49	Increased yield potential without changing plant height or maturity	Poza Rica	Among-family sibs	Recombine sibs	Reciprocal sibs	IPTT

Table 3. Advanced populations, traits emphasized in their improvement, and the corresponding pools, CIMMYT, 1980-81

Pop. no.	Population name	Group	Cycle of selection	Emphasis on trait(s)	Corresponding pool
21	Tuxpeño-1	2	4	Fall armyworm resistance	24
22	Mezcla Tropical Blanca	1	4	Downy mildew resistance	24
23	Blanco Cristalino-1	1	4	Sugarcane borer resistance	19
24	Antigua Veracruz 181	1	4	Fall armyworm resistance	22
25	Blanco Cristalino-3	2	4	White flint kernel	23
26	Mezcla Amarilla	2	4	Ear rot resistance	21
27	Amarillo Cristalino-1	1	4	Sugarcane borer resistance	25
28[a/]	Amarillo Dentado	2	4	Downy mildew resistance	26
29	Tuxpeño Caribe	2	4	Reduced plant height	24
30	Blanco Cristalino-2	2	1	White flint kernel	15
31[a/]	Amarillo Cristalino-2	2	1	Downy mildew resistance	17
32	ETO Blanco	1	3	Ear rot resistance	23
33	Amarillo Subtropical	1	1	Ear rot resistance	33
34	Blanco Subtropical	2	4	Reduced plant height	31
35	Antigua Republica Dominicana	1	3	Standability	18
36	Cogollero	2	4	Reduced plant height	26
39	Yellow QPM	2	1	Ear rot resistance	25 QPM
40	White QPM	2	4	Ear rot resistance	23 QPM
41	Templado Amarillo QPM	2	2	Ear rot resistance	33 QPM
42	ETO-Illinois	2	3	White dent kernel	32
43[b/]	La Posta	1	4	Streak virus resistance	24
44	AED Tuxpeño	1	3	Resistance to foliar diseases	32
45	Amarillo Bajio	1	1	Ear rot resistance	34
46	Templado Amarillo Cristalino	2	0	Ear rot resistance	29
47	Templado Blanco Dentado	1	1	Southwestern corn borer	32
48[c/]	Compuesto de Hungría	1	3	Stalk rot resistance	30
49	Blanco Dentado	2	0	Husk cover	20

a/ Being improved in cooperation with Thai National Corn and Sorghum Program
b/ Being improved in cooperation with International Institute of Tropical Agricultural (IITA)
c/ Being improved in cooperation with Turkish National Maize Program

Table 4. Progress in improving resistance to downy mildew and corn stunt diseases in collaborative research

Disease and population tested	Cycle of selection	Disease (%)	Yield (kg/ha)	Plant ht (cm)	Days to 50% silk
Downy mildew (Thailand)					
Tropical intermediate white flint	C_0	41 4	3836	185	68
	C_4	0	4404	160	66
Tropical yellow flint-dent	C_0	67.4	2684	199	68
	C_4	2.6	4490	183	66
Stunt disease (El Salvador)					
Tropical intermediate white flint	C_0	30.6	3337	206	49
	C_4	21.8	4120	200	49

Table 5. Performance of some corn stunt-resistant varieties against best local check in ten locations

Variety	Country	Yield of best stunt-resistant (kg/ha)	Yield of best check (kg/ha)	% of best check
Santa Rosa 8073	Mexico	4230	3525	120
Porrillo 8073	Mexico	3517	2420	145
Santa Rosa 8073	Panama	4556	3973	114
Santa Rosa 8073	Panama	4193	3138	133
Cuyuta 8073	Panama	4860	3773	128
Santa Rosa 8073	Nicaragua	4933	3316	148
Tlaltizapan 8073	Nicaragua	5775	4188	137
Santa Rosa 8073	Nicaragua	4093	3243	126
Santa Rosa 8073	Guatemala	5787	4606	125
Santa Rosa 8076	Guatemala	2808	1599	175

Table 6. International Progeny Testing Trials (IPTTs), 1980

Country	Trial number											
	22	23	24	27	32	33	35	39	43	47	45	Total
South America												
1. Argentina	–	–	–	–	–	–	–	–	–	–	–	0
2. Bolivia	–	–	1	1	–	–	–	–	–	–	–	2
3. Brazil	–	–	–	–	–	1	1	–	–	–	1	3
4. Chile	–	–	–	–	–	–	–	–	–	–	–	0
5. Colombia	–	–	–	–	1	–	–	–	–	–	–	1
6. Ecuador	–	–	–	–	–	–	–	1	–	–	–	1
7. Peru	–	–	1	–	–	1	1	–	–	–	–	3
8. Venezuela	–	1	–	–	–	–	–	–	–	–	–	1
Central America and Caribbean												
9. Costa Rica	–	–	–	–	1	–	–	–	1	–	–	2
10. El Salvador	–	–	–	–	–	–	–	–	1	–	–	1
11. Guatemala	1	–	–	–	–	1	–	1	–	–	–	3
12. Honduras	1	–	–	1	–	–	–	1	–	–	–	3
13. Nicaragua	1	–	–	–	–	–	–	–	–	–	–	1
14. Panama	–	–	1	1	–	–	–	1	–	–	–	3
15. Dominican Rep.	–	–	–	–	–	–	1	–	–	–	–	1
16. Haiti	–	–	1	–	–	–	–	–	–	–	–	1
17. Mexico												
a. CIMMYT	1	1	1	1	1	1	1	1	1	1	2	12
b. INIA	–	–	–	–	1	–	–	–	1	1	–	3
Africa												
18. Egypt	–	–	–	–	–	–	–	–	–	1	–	1
19. Ethiopia	–	–	–	–	1	–	–	–	–	1	–	2
20. Ghana	–	–	–	–	–	–	–	–	1	–	–	1
21. Ivory Coast	1	1	–	–	–	–	–	1	–	–	–	3
22. Kenya	–	–	–	–	–	–	–	–	–	1	–	1
23. Nigeria (NCRI)	–	–	–	–	–	–	–	–	–	–	–	0
24. Tanzania	–	–	–	–	1	–	–	–	1	–	–	2
25. Zaire	1	–	–	–	–	–	–	–	–	–	–	1
Asia												
26. India	–	1	–	–	–	1	–	–	–	–	–	2
27. Nepal	–	–	–	–	–	–	–	–	–	–	2	2
28. Pakistan	–	1	–	–	–	1	1	–	–	1	–	4
29. Philippines	–	1	1	1	–	–	–	–	–	–	–	3
30. Thailand	–	–	–	1	–	–	1	–	–	–	–	2
31. Turkey	–	–	–	–	–	–	–	–	–	–	1	1
Total	6	6	6	6	6	6	6	6	6	6	6	66

Table 7. International Progeny Testing Trials (IPTTs), 1981

Country	Trial number												
	21	26	28	29	30	31	34	36	40	41	46	49	Total
South America													
1. Bolivia	–	–	–	–	–	–	–	–	–	1	–	–	1
2. Brazil	1	–	1	–	–	–	–	1	–	–	1	–	4
3. Colombia	–	–	–	1	1	–	–	–	–	–	–	–	2
4. Peru	–	1	1	–	–	1	–	1	–	–	1	–	5
5. Venezuela	–	–	–	1	–	–	–	–	–	–	–	–	1
Central America and Caribbean													
6. Costa Rica	–	1	–	1	–	–	–	–	–	–	–	–	2
7. Guatemala	–	–	–	–	–	–	1	–	1	–	–	–	2
8. Honduras	1	–	–	–	1	–	–	–	1	–	–	–	3
9. Nicaragua	–	–	–	1	–	–	–	–	–	–	–	–	1
10. Panama	–	–	1	–	–	–	–	1	–	–	–	–	2
11. Dominican Rep.	–	–	–	–	–	–	–	1	–	–	–	–	1
12. Mexico	1	1	–	1	1	–	1	1	1	1	1	1	10
Africa													
13. Egypt	–	–	–	–	–	–	1	–	–	–	–	–	1
14. Ethiopia	–	1	–	–	–	–	1	–	–	–	1	–	3
15. Ghana	1	–	–	–	–	–	–	–	1	–	–	–	2
16. Ivory Coast	–	–	1	1	1	1	–	–	–	–	–	–	4
17. Nigeria	–	–	–	–	–	–	–	–	1	–	–	1	2
18. Rep. South Africa	1	–	–	–	–	–	–	–	–	–	–	–	1
19. Tanzania	–	–	–	–	–	–	1	–	–	–	–	–	1
20. Zimbabwe	1	–	–	–	–	–	–	–	–	–	–	1	2
21. Zaire	–	–	–	–	–	–	–	–	–	–	–	1	1
Asia													
22. Indonesia	–	–	1	–	–	–	–	–	–	–	–	–	1
23. India	–	1	–	–	1	1	1	–	–	1	1	–	6
24. Pakistan	–	–	–	–	–	1	–	–	–	1	1	–	3
25. Philippines	–	–	–	–	–	–	–	1	1	–	–	–	2
26. Thailand	–	1	1	–	–	1	–	–	–	–	–	–	3
27. Turkey	–	–	–	–	–	–	–	–	–	1	–	–	1
Total	6	6	6	6	5	5	6	6	6	5	6	4	67

Table 8. Summary of coefficients of variation (CV) and relative efficiency (RE) of lattice design for grain yield, 1981 International Progeny Testing Trials (IPTTs)

RE (%)	CV (%)							
	6-10	11-15	16-20	21-25	26-30	31-35	over 35	Total
Less than 100			2					2
100 – 115	6	15	7	2	1	2		33
116 – 125		4		2				6
126 – 150		2	2					4
151 – 175				1				1
176 – 200			1	2				3
Over 200				1				1
Total	6	21	12	8	1	2	–	50

Table 9. International Experimental Variety Trials (EVTs) and Elite Variety Trials (ELVTs) distributed in 1980 and 1981

Trial	No. participating countries	No. trials sent
1980		
EVT 12	42	68
EVT 13	41	61
EVT 14A	43	71
EVT 14B	39	58
EVT 15A	45	65
EVT 15B	23	35
EVT 16	40	71
ELVT 18A	55	88
ELVT 18B	46	77
ELVT 19	37	59
ELVT 20	40	66
1981		
QPMT 11A	55	105
QPMT 11B	37	67
ELVT 18A	61	133
ELVT 18B	68	155
ELVT 20	48	79
EVT 7	8	42

Table 10. Comparison of the best experimental varieties to the best check (tropical late white maize)

Variety	Country-location	Yield % best check	Days silk	Plant height
Across 7822	Brazil, Guaira	132	– 4	– 7
	Venezuela, San Joaquin	116	– 1	– 6
	El Salvador, San Andres	132	+ 1	– 9
	Mexico, Obregon (2)	133	+ 1	– 30
	Zaire, Kaniama	102	– 4	– 13
Cuyuta 7929	Venezuela, Macapo	133	– 4	– 5
	Mexico, La Huerta (Jal.)	164	– 1	–
	Mexico, Poza Rica	112	– 2	– 16
	Mozambique, Umbeluzi	113	– 2	–
Across 7843	Bolivia, Iboperenda	109	+ 3	+ 29
	Guatemala, Cuyuta	107	+ 4	+ 39
	Guatemala, La Maquina	116	+ 2	+ 54
	Mexico, Cotaxtla	106	– 1	+ 2
	Burundi, IMBA	149	–	+ 1
	Malawi, Chitala	126	+ 6	+ 25
Poza Rica 7921	Benin, Sekou	135	– 2	+ 1
	Ghana, Kwadaso	147	– 5	– 19

Table 11. Comparison of the best experimental varieties to the best check (tropical late yellow maize)

Variety	Country-location	Yield % best check	Days silk	Plant height
Ferke (1) 7928	Argentina, Leales	102	+ 1	– 3
	Argentina, Pergamino	107	+13	+ 73
	Belize, Central Farm	162	– 6	– 34
	Mali, Sotuba	119	– 1	+ 25
Ferke 7928	Venezuela, San Joaquin	109	– 1	+ 29
	El Salvador, San Andres	148	+ 2	+ 3
	Panama, Chiriqui	113	0	– 4
	Panama, Rio Hato	111	0	– 5
Obregon 7936	Bolivia, Iboperenda	112	– 3	– 38
Across 7824	Venezuela, Acarigua	124	– 1	+ 7
	Mexico, Obregon	111	– 7	– 16
	Mozambique, Umbeluzi	145	– 1	–
	Philippines, Karan	121	+ 2	+ 13

Table 12. Comparison of the best experimental varieties to the best check (tropical intermediate maize)

Variety	Country-location	Yield % best check	Days silk	Plant height
Tocumen (1) 7926	Ecuador, Pichilingue	104	− 3	− 26
	Guatemala, Cuyuta	103	+ 3	0
	Honduras, San Pedro Sula	102	− 6	− 16
	Botswana, Good Hope	103	0	+ 1
Poza Rica 7926	Venezuela, Acarigua	114	− 1	− 26
	Nicaragua, Sebaco	129	+10	+ 29
	Panama, Chiriqui	101	− 5	− 15
	Ghana, Nyankpala	105	− 3	− 26

Table 13. Comparison of the best experimental varieties to the best check (tropical early maize)

Variety	Country-location	Yield % best check	Days silk	Plant height
Jutiapa (1) 7930	Venezuela, Acarigua	114	− 4	− 6
	Mali, Sotuba	136	− 11	− 4
	Senegal, Sefa	109	− 10	− 18
	Philippines, Karan	111	− 9	− 3
Pirsabak (1) 7930	Guatemala, Cuyuta	106	− 3	− 12
	Guatemala, La Maquina	105	− 4	− 5
	Nigeria, Ikenne	117	− 7	− 17
	Pakistan, Yousafwala	102	− 3	+ 4

Table 14. Comparison of the best experimental varieties to the best check (subtropical maize)

Variety	Country-location	Yield % best check	Days silk	Plant height
Across 7842	Mexico, Tlaltizapan	106	-- 4	– 17
	Burundi, Mosso	140	– 8	– 30
	Jordan, Dier Alla	133	+ 1	+ 20
	Nepal, Rampur	134	– 2	– 2
Across 7844	Mozambique, Mutuali	110	– 6	–
Cotaxtla 7844	Rep. S. Africa, Potch	119	+ 7	– 7
	Swaziland, Mangcongo	105	–	– 36

Table 15. Comparison of later cycles EVs and reference entries (REs) originating from same population, 1981 trials

Trial	Number of locations tested	Population number	Population name	No. of EVs with yields higher than REs	No. of EVs with yields lower than REs
EVT 11A	53	40	White QPM	1	1
EVT 11B	31	41	Templado Amarillo QPM	2	0
ELVT 18A	72	28	Amarillo Dentado	2	0
		29	Tuxpeño Caribe	0	2
ELVT 18B	86	26	Mezcla Amarilla	1	0
		35	Ant. Rep. Dominicana	1	0
ELVT 20	48	34	Blanco Subtropical	1	0

Quality Protein Maize Improvement

CIMMYT has been actively engaged in improving the quality of protein in maize for the past fifteen years. From an initial modest research effort, CIMMYT greatly intensified its research activities in 1970 because of financial support provided by the United Nations Development Programme. Initially, research emphasis was on producing soft endosperm quality protein maize (QPM) materials. Such emphasis continued for several years. The QPM versions of several normal genotypes were developed and evaluated systematically, both at the national and international levels. The results of QPM trials and the experience of growing QPM materials on commercial production plots brought awareness of several undesirable attributes and crucial problems associated with such materials. The key problems that acted as the stumbling block in the promotion of these materials were reduced grain yield, unacceptable soft and chalky kernel appearance, greater vulnerability to ear rot organisms, more severe damage by stored-grain pests, and slower drying following physiological maturity of the grain. These problems encountered in QPM have been known for a long time but, unfortunately, very little was done to alleviate them until the early 1970s. It was almost a decade after the work had begun that these limitations were widely recognized and considerable effort devoted to overcoming them.

Realizing the complexity of the problems in QPM, CIMMYT started exploring new ideas and approaches to search for an alternative that could aid in remedying defects and thus improve the acceptability of these materials. The only approach which appeared promising involved the accumulation and exploitation of genetic modifiers of the opaque-2 locus. This has proven to be a most effective breeding strategy. Before this breeding strategy could be used, however, suitable donor stocks had to be developed with vitreous endosperm and with protein quality very similar to that of soft endosperm types. As soon as this objective was accomplished in 1974, a major switch-over in the breeding approach was made to manipulate the beneficial effects of the opaque-2 gene along with the genetic modifiers. This was done to alleviate complex and inter-related problems and to develop a wide array of QPM germplasm. Good progress has been made to date.

Research Philosophy

Competitive performance of QPM materials with normal genotypes is essential to accelerate farmer acceptance of these materials. CIMMYT has long recognized that QPM genotypes can be developed that will generate the same calories as the normals with quality protein as a bonus. To accomplish this, CIMMYT breeders have followed a conservative approach in at least accepting the initial boost in lysine content to be of a sufficient magnitude. Having accepted this, they have felt no need to place any further major emphasis on enhancing lysine content. Rather, they believe that effort should be directed toward maintaining the protein quality at a level of 9-10 percent protein in the whole grain. This strategy has helped in breeding superior high-yielding QPM genotypes with major emphasis on the remaining areas of potential improvement.

Selecting the best ears of QPM, which yields as much as normal maize and has the same kernel type, but is far superior in protein content

Breeding Objectives
The general breeding objectives in the quality protein maize breeding program comprise the following specific ones:

- Develop agronomically superior QPM materials for a range of environments, maturities, colors and textures to meet the needs of the national programs;
- Continue research emphasis on using direct and indirect field techniques and new breeding strategies to alleviate crucial problems associated with QPM during the improvement process;
- Add new dimensions to QPM germplasm development and management to permit selection for higher yield and stability in varied environments around the world;
- Continue breeding emphasis on accumulation of additional favorable modifiers without sacrificing protein quality in QPM materials at all levels. In accumulating such modifiers, the stability of modifiers should also be a key consideration;
- Explore new ideas related to QPM which may have some bearing on nutritional, breeding, and seed production aspects;
- Continue improvement of QPM materials in floury backgrounds, with special characteristics for the Andean region;
- Continue building resistance to important maize diseases by selection under natural conditions and through artificial inoculations;
- Distribute QPM germplasm through international testing of progenies, experimental varieties, elite experimental varieties, and other superior recombinations, and
- Continue the monitoring of more advanced QPM materials in the biological assay.

Progress in Overcoming Problems in QPM Materials

Improvement of QPM materials is done concomitantly with major emphasis on selection against problems associated with QPM. Good progress has been made in at least substantially minimizing the problems affecting QPM.

Kernel appearance
The QPM materials no longer have a soft and chalky appearance. The kernel phenotype has been altered completely to look like normal maize. Figure 1 shows continuing improvement in kernel phenotype, observed in most materials undergoing improvement.

Yield
Grain yield of several QPM materials is fairly comparable to normal genotypes in the same genetic background or to the best normal genotypes in the same maturity range available in different national programs. A combination of several direct and indirect criteria have helped to achieve this objective, including selection against open kernel rows, better kernel weight and density in segregating generations, and accumulation of favorable modifiers for kernel weight. It has been achieved through continuous population improvement, using several selection schemes singly or in combination. Data on yield will be presented in the following sections of this report. Figure 2 shows continuous improvement in QPM materials for yield over the years.

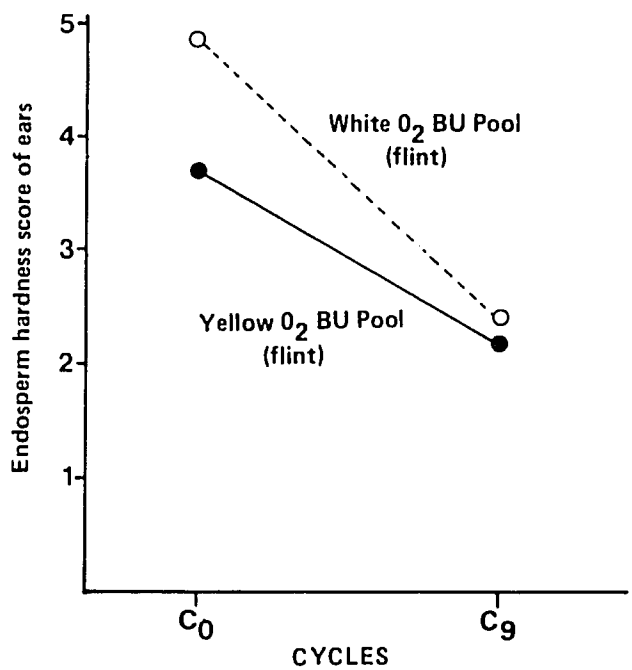


Figure 1. Endosperm hardness score of cycles of selection in two Quality Protein Maize Pools

Ear rots
Ear rots have been reduced substantially in QPM materials currently being handled in the breeding program. Reduction in ear rot susceptibility of QPM materials has resulted from factors including reduction in germplasm influence of original opaque-2 donor stocks through backcrossing, selection against pericarp splitting, better drying ability following physiological maturity of the grain, and through selection against ear rots under natural and artificial conditions. Though good progress has been made, there is still a tendency in QPM materials to exhibit slightly higher than average incidence to ear rots. (Figure 3).

Drying following physiological maturity of the grain
Drying of QPM kernels does not pose any serious problem. At harvest, QPM materials register more or less the same moisture content as the normals. The slower drying of opaques has been somewhat corrected by early harvesting and through selection of productive and faster-drying genotypes. In materials undergoing improvement through international progeny testing trials, data on yield and moisture content are given special consideration in addition to other important agronomic characters (Figure 4).

Germplasm Development and Improvement
A wide array of QPM germplasm has been developed over the years. This has been accomplished through the following two broad breeding approaches.

Conversion program
The conversion program to obtain QPM versions has been under way for several years and was continued in the same fashion as reported in the earlier reports. In the conversion program, a modified backcrossing scheme is used which combines advantages of both backcrossing and recurrent selection programs. This breeding approach involves the use of two genetic systems, a simple system involving the opaque-2 gene to improve the protein quality and a more complex polygenically controlled system of genetic modifiers to overcome and improve the undesirable side-effects of the opaque-2 gene. The latter system has been superimposed on the former to eliminate the undesirable phenotypic effects of the opaque-2 gene in the desired direction. The use of a backcross-cum-recurrent-selection program permits continuous accumulation of modifiers while maintaining their frequency by the ensuing backcrosses, and permits use of the improved version or the latest cycle of selection of the recurrent parent. Additional selection criteria have been introduced into this scheme to permit screening of stable modifiers.

During the conversion process, special attention is devoted at selection time to improved performance of QPM materials for grain yield, seed appearance, reduced ear rot incidence, and faster grain drying ability. In order to improve these characters, selection is practiced against open spaces between kernel rows, dull modifiers, popped kernels, and slow-drying ears.

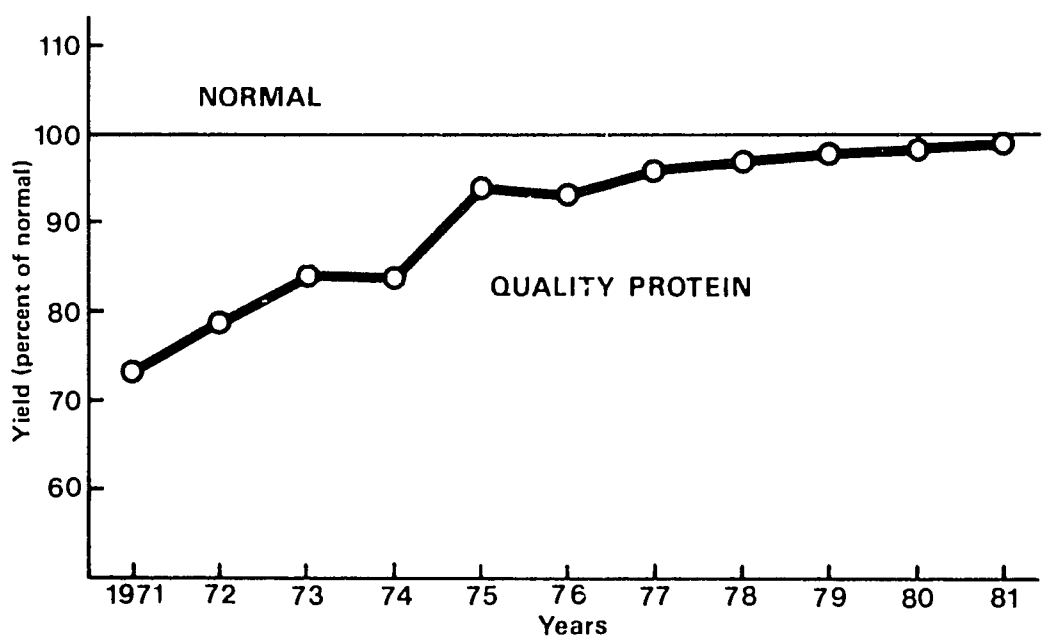


Figure 2. Grain yield of superior QPM as percentage of normal checks in different years across all test locations

In the conversion of advanced unit populations to QPM, a total of 5,013, 5,799, 5,843, and 5,404 families were handled during the years 1980A, 1980B, 1981A, and 1981B, respectively (Table 1). In several materials, the QPM families from each material are screened for stability in the B season, followed by recombination of the superior ones in the A season. Also in the B season, when the families are being screened for stability, within-family variation is capitalized on by making either self or within-family sibs. In the A season, when selfs or within-family sibs are grown, several families exhibiting deleterious effects are rejected. The selected families are recombined so as to cross each family to at least four to six other families. The pollinated ears are harvested somewhat earlier in both seasons to permit visual selection of faster-drying ears. Heavy selection pressure is exerted for endosperm modification at ear level during harvest and at kernel level during the seed preparation process.

The conversion of some gene pools was also continued during the years 1980 and 1981. Their improvement process continued either at Tlaltizapan or at Poza Rica, depending upon the adaptation of the material. Some pools were screened only for stability of endosperm modification, as was done with the QPM families of the Advanced Unit conversion. The number of families that were handled from three tropical and five subtropical gene pools is shown in Table 2.

During 1980 and 1981, QPM versions of Advanced Unit populations and the pools that had genetic and phenotypic resemblance were merged. This merging process was executed both in tropical and subtropical QPM materials that had originated from the conversion program. The QPM families of Tuxpeño-1, Blanco Cristalino-1, Amarillo Cristalino-1, Amarillo Dentado, and Hungarian Composite were merged with QPM families of pools 24, 19, 25, 26 and 30, respectively.

Some other materials were also merged. The quality protein versions of pool 15 and Blanco Cristalino-2 were also merged and the resulting material will be handled under the name of Blanco Cristalino-2 QPM. Similarly, Seleccion Precoz QPM and pool 17 QPM versions were merged to provide an equivalent version of Amarillo Cristalino-2 QPM. Pool 18 QPM was also merged with QPM version of Ant. x Rep. Dom. QPM.

As pointed out earlier, QPM families from nine populations were planted either at Poza Rica and Obregon or at Tlaltizapan and Ciudad Obregon. A total of 2,596 families were planted at two locations during the season 1980B for agronomic evaluation and for stability of modified kernel phenotype. Most of the families showed good stability in both locations. There were very few families that exceeded a difference of one in endosperm modification score in two locations (Table 3). Also during 1981B, eight tropical and five subtropical QPM materials were screened for stability of kernel modification and for agronomic performance. The mean endosperm modification score and the ear aspect score of different QPM

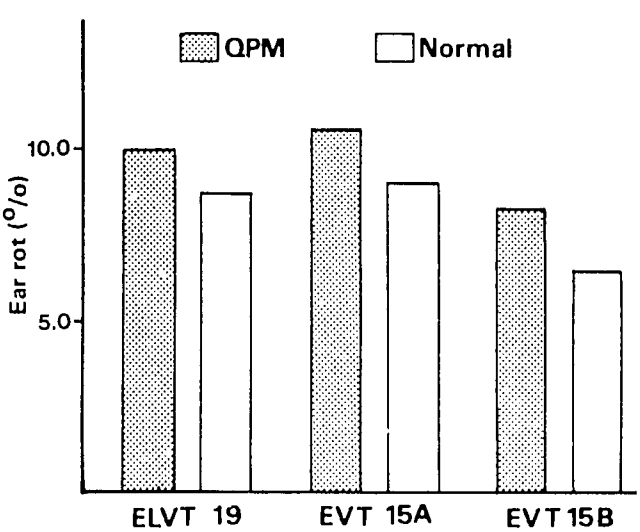


Figure 3. Mean performance of QPM entries and normal checks across locations in different trials for ear rot, 1980

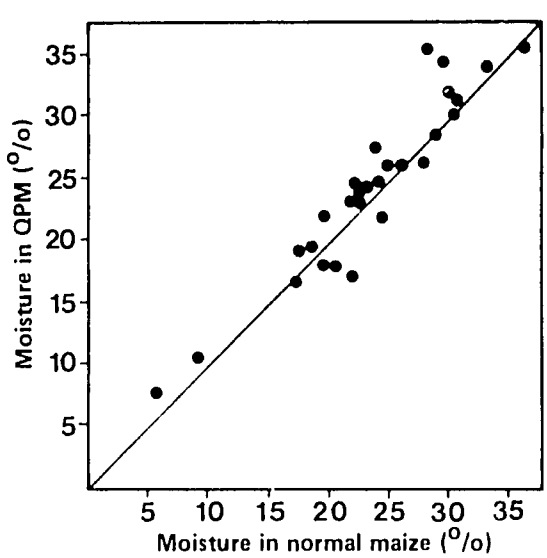


Figure 4. Moisture levels in normal and QPM entries silked at the same time, ELVT-19, 1980

materials is given in Table 4. Excepting Tuxpeño-1 QPM, the ratings were fairly similar in the two locations for both characters. Over 90 percent of the families showed a difference no greater than one in two locations for endosperm modification.

During the period being reported, QPM versions of materials in special projects and collaborative research were also merged with the QPM versions of the advanced unit materials or the pools. The resulting materials will be handled as part of the conversion program of the advanced unit populations or the pools and will be subjected to the backcrossing-cum-recurrent-selection program.

The kernel modification score of most QPM materials undergoing conversion has improved over the cycles. Also, a higher percentage of the families now shows stability over locations. With respect to ear rots and moisture percentage at harvest, the QPM versions perform similarly to the counterpart normal populations. Data on yield and other agronomic characters of normal and QPM versions is presented in the following sections of this report.

Development and improvement of QPM gene pools
Four tropical and three subtropical QPM gene pools are being improved continuously by half-sib selection. The number of families that were handled in each pool during each cycle is given in Table 5. Four additional cycles of selection were completed during 1980 and 1981. In every cycle, only the superior fraction of the gene pool possessing good protein quality entered into the male mix. Between and within-family selection was practiced for all the characters before and at harvest time. With respect to genetic modifiers, the selection process was further supplemented by selection of better modified kernels from each ear for planting the next season. Selection pressure was exerted in male rows for all characters that can be observed before or at flowering.

During 1980B two tropical yellow QPM pools were planted at Poza Rica and Obregon. Similarly, three subtropical QPM pools were grown at Tlaltizapan and Obregon. Good modified ears from good plants in the selected families were saved for continuing selection in the next season. This sort of selection should help improve the adaptation of the pools.

The progress in different QPM pools was evaluated in special trials involving different cycles of selection. The data are presented in Tables 6 and 7. It can be seen from the tables that later cycles show significant improvement in reducing plant height, reducing the number of soft ears, and

CIMMYT scientists and visitors from Guatemala and Honduras examine harvest of quality protein maize

improving ear aspect and kernel phenotype. In some pools, the later cycles became somewhat earlier, though this was unintentional. Grain yield showed improvement in some pools, while in others it remained unchanged. The frequency of different modified classes showed a dramatic change (Table 8). The completely modified kernels and 75 percent modified kernels showed an increase in frequency while the 0 percent modified class was practically eliminated. The protein content and quality has been maintained in successive cycles of selection (Table 9).

Four QPM pools, namely Yellow flint QPM, Yellow dent QPM, Temperate x tropical QPM (flint), and Temperate x tropical QPM (dent) are being continously improved for ear-rot resistance through artificial inoculations. Half of the row in each family was inoculated with *Fusarium moniliform* during each season. Artificial inoculations of 500 selected plants in male rows with stalk and ear rot organisms have also been initiated recently. About 50 ears exhibiting good resistance to both diseases are selected each cycle. These selected ears are incorporated into the main body of the pool in the next cycle.

Building up resistance to *Helminthosporium turcicum* and *Polyspora sorghi* has recently been initiated in three subtropical QPM pools, namely Temperate x tropical QPM (flint), Temperate x tropical QPM (dent), and Temperate white QPM. The families from each of these pools are planted at Poza Rica and El Batan to screen for helminthosporium and rust, respectively. The selections from both those locations are ultimately recombined with selections from Tlaltizapan.

Population Improvement Program

The intra-population improvement program using full-sib family selection is being used in several quality protein maize populations. The materials undergoing improvement are discussed below.

Improvement of QPM materials in the Advanced Unit

Three quality protein maize populations form part of the Advaced Unit. All these materials have good kernel appearance with fairly good stability of kernel phenotype. The populations being handled in the advanced unit are:

- Population 39 - Yellow QPM
- Population 40 - White QPM
- Population 41 - Templado Amarillo QPM

As with normal populations, these QPM materials are tested internationally in progeny trials. The improvement process involves the testing of 250 full-sib families in different sites, including one in Mexico. The test sites preferably are located in different countries. In 1980, only population 39 and, in 1981, populations 40 and 41 were sent out for progeny evaluation. The distribution of these IPTTs is given in Table 10.

The superior 30 to 40 percent of the families were selected on across-location performance. Within-family improvement in the selected families was done for ear rot resistance. In the following cycle, three resistant selfed ears from each family were saved. The selected selfed progenies were recombined through bulk sibbing, using only the selected plants.

In addition to the improvement of each of the three populations, site-specific and across-site experimental varieties were developed by recombining approximately 10 superior families. In all, 13 experimental varieties are being developed from the 3 populations. Mean performance of 10 superior families used in the formation of each experimental variety is given in Table 11. The mean of the selected families going into the formation of experimental varieties showed a selection differential for yield ranging from 17.3 percent to 22.6 percent, 18.0 to 22.0, and 14.0 to 25.5 in populations 40, 41 and 39, respectively. For plant height and days to flower the differences were negligible. Detailed data is provided in the Maize International Testing Reports for 1980 and 1981.

Improvement of QPM materials in the conversion program

The progenies from three subtropical QPM versions and three tropical versions were evaluated in progeny trials within Mexico at two locations. The number of full-sib families included in each progeny trial varied from one QPM population to the other. The names of the QPM versions, the number of full-sib families evaluated in each, and data on yield and other agronomic characters are given in Table 12. The selection differential for yield in percent ranged from 4.2 percent to 9.4 in different materials. Days to silking, maturity, and ear height remained practically unchanged. Both ear aspect and endosperm modification showed slight improvement.

Highland QPM Program

In the highland program, QPM versions of both floury and nonfloury gene pools are being developed. The opaque-2 versions of old pools 3 and 8 were merged during 1979 to form an equivalent quality protein version of new pools 1 and 2. The ears from two pool conversions were merged in a half-sib crossing block in El Batan and Toluca. Two additional cycles of recombination and selection were completed during the year 1980-81. Important selection criteria in these pools involve selection for large floury kernels and resistance to ear rot-causing organisms.

A yellow QPM version of pool 3 is also being developed. Pool 3 was crossed with an opaque-2 donor during 1979. The F_1 ears were advanced to F_2 by selfing during 1980. Because of the difficulty of identifying opaque-2 kernels, the selfed F_2 ears were saved during 1981. The F_2 plants were selfed again to obtain F_3 ears. Following harvest in 1981, the F_3 ears will be analyzed in the quality protein laboratory to identify F_3 ears that are homozygous for the opaque-2 gene. The F_3 ears or families showing good protein quality will be recombined in 1982.

Equivalent QPM versions of two nonfloury pools, 5 and 6, were developed during 1979 by merging QPM versions of the previous 14 highland pools. Additional cycles of recombination and improvement were done during 1980 and 1981. These pools are receiving major emphasis for improvement of kernel modification through the accumulation of favorable modifiers. Selection pressure is also being exerted against ear rots under natural conditions. In addition to the QPM versions of pools 5 and 6, the QPM version of Mezcla Amarilla Planta Baja x Illinois lines was further improved through selection during 1980 and 1981. It is receiving pressure for improved kernel modification, as are pools 5 and 6.

In addition to the above conversions, two QPM materials, floury-1 opaque-2 composite and highland modified opaque-2 composite, are being improved for the highland areas. The former has floury endosperm while the latter has modified endosperm. Two additional cycles of recombination were completed in a half-sib system. In the floury opaque-2 composite, improvements are being made for increased kernel size and ear rot resistance. On the other hand, in the highland modified opaque-2 composite, the emphasis continues to be on accumulating favorable modifiers so as to change the endosperm to more resemble normal maize.

Selection for Increased Oil Content

Selection for high oil content has been underway in two QPM populations to improve the energy value of the grain. The two QPM populations are Temperate x tropical QPM (dent) and White dent QPM. In Temperate x tropical QPM (dent), selection work was initiated in 1979. Since then, three cycles of selection have been completed. The data are shown in Table 13. The oil content in the whole grain has increased progressively from 4.29 percent in C_0 to 5.21 percent in the latest cycle. Similarly, in the white dent QPM population, three cycles of selection have been completed. The data show that oil content has increased over the successive cycles. The latest cycle registered an oil content of 4.95 percent in the whole grain compared with 3.50 in the varietal cycle (C_0).

Simply Inherited Modifiers

Research on the identification of simply inherited modifiers is continuing. Several lines possessing modified endosperm probably have a simple genetic system of modifiers. Some of the promising QPM lines have been crossed to normal maize and then advanced to F_2. The segregation pattern of the selected F_2 ears is being investigated to find the number of genes involved, influence on kernel weight and density, and effect on protein quality.

Introduction of the Dominant Gametophytic Factor

It is hoped that the introduction of the dominant gametophytic factor will serve as a useful genetic mechanism to prevent contamination of QPM materials by normal pollen. A few donor stocks carrying this gene have been procured from the USA and have been crossed with the four best quality protein maize materials having excellent kernel phenotype. A few backcrosses have already been attempted with recurrent parent QPM materials, while retaining the desired factor under transfer.

Development of Colored Seed Marker Stocks

This work has been initiated recently, the idea being to develop seed stocks in normal maize which could be used for partial contamination of QPM materials for the selection of better kernel weight and density. It is extremely important that colored seed markers be homozygous and show pollen influence through the xenia effect in all the contaminated kernels on the QPM ears. Some good source stocks have been identified which could be used for this purpose. This character is already being transferred to some promising normal materials in different maturity groups. It is envisaged that suitable good colored seed markers will be developed soon.

Comparison of QPM Versions and their Normal Counterparts

Ten QPM versions and their normal counterparts have been compared in special trials for two years. In these trials, four-row plots were used. At flowering time, the normals were completely detasseled to prevent contamination of QPM entries. In the QPM entries, the two central rows were detasseled to reduce upward bias in the normals resulting from the detasseling process. Combined data, pooled over locations and years, are presented in Table 14. Four QPM entries had grain yields of 95 percent and above of that of the normal counterpart. Four entries had yields ranging between 91.2 and 92.9 percent of that of their corresponding normal entries. Two, Mezcla Tropical Blanca and Blanco Cristalino-1, yielded significantly less than their normal counterparts. Ear height differences did exist in some QPM entries and their normal versions, but these differences were not large. QPM versions appeared to be somewhat earlier by a few days, but had a general tendency to show slightly higher susceptibility to ear rots.

Performance of QPM Materials in International EVTs and ELVTs

During 1980 and 1981, several QPM trials were sent to different countries around the world. The Experimental Variety Trials EVT-15A, EVT-15B, and the Elite Experimental Varity Trial ELVT-19 were distributed during 1980, while Quality Protein Maize Trials QPMT-11A and QPMT-11B were sent out during 1981. The distribution of the trials by region was presented in Table 10.

In EVT-15A, out of 63 locations where this trial was sent, the data have been retrieved from at least 30 locations. A summary of the results is presented in Table 15. Several experimental varieties derived from White QPM (Population 40) had superior performance and in many countries yielded almost equal to or in some cases even better than, the best normal check entries. Poza Rica 7940, Ferkessedougou 7940, and Guanacaste 7940 were the most outstanding experimental varieties. They were somewhat earlier and showed slightly higher incidence of ear rots.

The results of EVT-15B from 1980 are presented in Table 16. Only 18 locations out of 31 have reported data. The performance of QPM entries in this trial was not consistent. However, Obregon 7941 was by far the best experimental variety. The QPM entries were earlier and shorter in several locations. The ear rot incidence in general was higher in QPM entries, except in some locations where normals registered an increased incidence.

In ELVT-19, 15 entries were evaluated, including three normal checks. The trial was sent to 57 locations; however, the data have been retrieved from only 29 locations. The two outstanding entries in this trial were Across 7740 and La Posta H.E.o2. These two entries and other QPM entries were generally earlier and shorter, but had a general tendency to exhibit slightly more ear rot. The differences in moisture content between QPM and normals were almost negligible except in some locations (Table 17).

From the 1981 trials, 17 locations have reported data on QPMT-11A and 14 locations on QPMT-11B. These data are presented in Tables 18 and 19. In QPMT-11A, several entries, Guanacaste 7940 and Tuxpeño-1 QPM, performed as well as or better than the best normal check in different countries. In QPMT-11B, several entries registered outstanding performance and yield compared to the normal check entry. The best performing entries in this trial were Temperate white QPM, Amarillo Bajio x Maices Argentina QPM, and Amarillo Subtropical QPM.

Future Considerations and Outlook

With the earlier problems plaguing QPM resolved or on their way to resolution new efforts should emphasize systematic merging of QPM germplasm to improve yield dependability and adaptation through international testing. Thus new QPM populations will be added to the advanced unit to permit selection for higher yield and stability in varied environments around the world. Multilocation performance of the materials will also facilitate accumulation of stable modifiers and will contribute to more uniform kernel appearance and greater market acceptance. This will permit further refinement of QPM genotypes to meet phenotypic descriptions and requirements of materials in several national programs. Range of variation in maturity and kernel texture needs to be reduced to the bare minimum. Also, since most of the groundwork in developing QPM germplasm has been accomplished within Mexico, future breeding plans and strategies may follow a course very similar to those being practiced in the normal materials.

The future outlook of QPM material has improved considerably over the years. The situation is likely to improve still further as better and more productive genotypes are made available to different national programs. Promotion, commercial production, and utilization of QPM should now receive priority, at least in those countries where QPM has given good performance.

Table 1. Conversion of advanced unit populations to QPM

Material	No. of families grown			
	1980B	1981A	1981B	1982A
Tuxpeño-1 QPM	283	344	413	375
Mezcla Tropical Blanca QMP	220	255	222	286
Blanco Cristalino QPM	317	340	584	417
Ant. x Ver. 181 QPM	382	352	336	317
Mix. 1-Col. Gpo. 1 x ETO QPM	236	213	197	174
Mezcla Amarilla QPM	115	200	242	197
Amarillo Cristalino QPM	173	359	385	260
Amarillo Dentado QPM	364	528	332	256
Tuxpeño Caribe QPM	314	371	375	318
Blanco Cristalino-2 QPM	148	188	206	108
Amarillo Cristalino-2 QPM	415	403	396	366
ETO Blanco QPM	224	202	183	195
Amarillo Subtropical QPM	239	359	305	361
Blanco Subtropical QPM	348	375	311	441
Ant. Rep. Dom. QPM	302	299	213	141
Cogollero QPM	49	–	–	–
ETO-Illinois QPM	244	379	324	295
La Posta QPM	211	234	204	196
Amarillo Bajio QPM	207	223	201	206
Hungarian Composite QPM	132	175	154	202
Templado Amarillo Cristalino	–	–	260	293
Total	5013	5799	5843	5404

Table 2. Conversion of tropical and subtropical gene pools to opaque-2

Pool no.	Name	No. of families grown 1980B	1981A	1981B	1982A
	Tropical gene pools				
16	Tropical early white dent	177	215	148	108
20	Tropical intermediate white dent	112	75	137	122
23	Tropical late white flint	158	187	193	194
	Total	447	477	478	424
	Subtropical gene pools				
27	Subtropical early white flint	113	95	160	167
29	Subtropical early yellow flint	135	216	–	–
31	Subtropical intermediate white flint	148	242	266	356
33	Subtropical intermediate yellow flint	67	258	316	387
34	Subtropical intermediate yellow flint	218	286	289	330
	Total	681	1097	1031	1240

Table 3. Variation in endosperm modification score of QPM families from different QPM materials grown in Poza Rica and Ciudad Obregon, 1980

Material	No. families evaluated	Frequency of difference in endosperm modification score 0.0	1.0	2.0	3.0
Tuxpeño-1 QPM	224	96	116	12	0
Mezcla Tropical Blanca QPM	220	97	107	16	0
Blanco Cristalino-1 QPM	302	134	154	13	1
Mix. 1-Col. Gpo.1 x Eto QPM	177	65	96	15	1
Amarillo Cristalino-1 QPM	449	109	208	121	11
Amarillo Dentado QPM	488	142	231	108	7
Yellow Flint QPM	122	37	61	22	2
White Flint QPM	257	74	128	47	8
Yellow Flint QPM pool	576	310	244	21	1
Yellow Dent QPM pool	419	204	195	20	0
Temperate x tropical QPM (flint)	464[a]	209	227	26	2
Temperate x tropical QPM (dent)	448[a]	189	236	23	0
Temperate white QPM	500[a]	240	234	25	1

[a] Grown in Tlaltizapan and Obregon

Table 4. Performance of full-sib families of tropical and subtropical QPM materials grown at Poza Rica and Tlaltizapan, 1981

QPM population	Endosperm modification score[a]			Ear aspect score[b]		
	Poza Rica	Tlaltizapan	Mean	Poza Rica	Tlaltizapan	Mean
Tropical QPM materials						
Tuxpeño-1 QPM	3.5	1.9	2.7	3.3	2.5	2.9
Mezcla Tropical Blanca QPM	2.1	1.9	2.0	2.9	2.5	2.7
Blanco Cristalino-1 QPM	2.1	1.9	2.0	2.8	2.2	2.5
Amarillo Cristalino-1 QPM	2.5	2.0	2.3	3.3	2.3	2.8
Amarillo Dentado QPM	2.3	2.2	2.3	3.2	2.9	3.1
Tuxpeño Caribe QPM	2.1	2.0	2.1	3.0	2.9	2.9
La Posta QPM	2.5	2.1	2.3	3.2	2.7	2.9
Pool 23 QPM	2.3	2.1	2.2	3.3	2.8	3.1
Subtropical QPM materials						
Amarillo Subtropical QPM	2.5	2.2	2.3	3.0	2.9	2.9
Eto-Illinois QPM	2.5	2.0	2.3	3.1	2.7	2.9
Amarillo Bajio QPM	2.5	2.1	2.3	2.9	2.9	2.9
Pool 33 QPM	2.3	2.1	2.1	2.8	2.7	2.7
Pool 34 QPM	2.3	2.6	2.5	3.0	3.1	3.1

a/ 1 - 5 scoring scale (1 = good modification, 5 = poor modification)
b/ 1 - 5 scoring scale (1 = good, 5 = poor)

Table 5. QPM gene pools

QPM pool	Breeding scheme	Cycle of selection 1982A	No. of families grown			
			1980B	1981A	1981B	1982A
Tropical QPM pools						
Tropical white flint QPM	Half-sib	C_{15}	540	371	416	512
Tropical white dent QPM	Half-sib	C_{15}	525	279	538	512
Tropical yellow flint QPM	Half-sib	C_{15}	642	672	447	512
Tropical yellow dent QPM	Half-sib	C_{15}	421	447	399	512
Subtropical QPM pools						
Temperate x tropical QPM (flint)	Half-sib	C_{15}	480	491	427	509
Temperate x tropical QPM (dent)	Half-sib	C_{15}	480	482	404	518
Temperate white QPM	Half-sib	C_9	510	518	545	576

Table 6. Comparison of different cycles of selection in four tropical QPM gene pools for yield and other agronomic characters, Poza Rica and Ciudad Obregon, 1980B

Gene pool	Cycle	Yield (kg/ha)			Days to silk			Plant height (cm)			Soft ears (%)			Endosperm modification score[a]			Ear aspect score[a]		
		Poza Rica	Cd. Obregon	Mean	Poza Rica	Cd. Obregon	Mean	Poza Rica	Cd. Obregon	Mean	Poza Rica	Cd. Obregon	Mean	Poza Rica	Cd. Obregon	Mean	Poza Rica	Cd. Obregon	Mean
White flint QPM	C_0	2400	2911	2656	57	60	59	193	196	195	64	96	80	5.0	4.9	5.0	4.7	4.1	4.4
	C_{11}	2504	2852	2678	54	58	56	174	182	178	4	5	5	1.9	1.6	1.8	2.6	2.1	2.4
LSD (.05)		351	308	–	1.3	2.5	–	13.1	9.3	–	6.7	9.0	–	0.6	0.6	–	0.5	0.4	–
White dent QPM	C_0	2784	3118	2951	55	57	56	213	191	204	72	96	84	4.5	4.9	4.7	4.2	4.0	4.1
	C_{11}	2753	3349	3051	55	56	56	186	194	190	8	10	9	1.9	1.7	1.8	2.6	2.1	2.4
LSD (.05)		280	254	–	0.9	2.0	–	13.5	18.8	–	7.6	10.2	–	0.6	0.5	–	0.6	0.4	–
Yellow flint QPM	C_0	2673	2722	2698	55	56	56	202	196	199	57	84	71	4.0	4.2	4.1	3.9	3.7	3.8
	C_{11}	2638	2677	2657	55	56	56	191	201	196	9	13	11	1.7	2.0	1.9	2.4	2.5	2.5
LSD (.05)		406	288	–	1.1	1.2	–	14.0	11.3	–	8.6	12.3	–	0.7	0.5	–	0.5	0.5	–
Yellow dent QPM	C_0	2477	2733	2605	55	58	57	205	200	203	67	89	78	4.0	4.0	4.0	3.9	3.7	3.8
	C_{11}	2413	2605	2509	55	57	56	201	184	193	8	21	15	1.9	2.1	2.0	2.6	2.5	2.6
LSD (.05)		222	309	–	0.6	1.1		7.8	16.9	–	13.4	11.6	–	0.6	0.6	–	0.5	0.5	–

[a] 1 - 5 scoring scale (1 = excellent, 5 = poor)

Table 7. Comparison of different cycles of selection in three subtropical QPM pools for yield and other agronomic characters, Tlaltizapan and Ciudad Obregon, 1980B

Gene pool	Cycle	Yield (kg/ha)						Plant height (cm)			Soft ears (%)			Endosperm modification score[a]			Ear aspect score[a]		
		Tlal-tizapan	Cd. Obregon	Mean	Tlal-tizapan	Cd. Obregon	Mean	Tlal-tizapan	Cd. Obregon	Mean	Tlal-tizapan	Cd. Obregon	Mean	Tlal-tizapan	Cd. Obregon	Mean	Tlal-tizapan	Cd. Obregon	Mean
Temp. x trop. QPM (flint)	C_0	6149	2726	4437	61	56	59	238	186	212	50	82	66	4.0	4.3	4.2	4.0	4.0	4.0
	C_4	6643	2736	4689	61	54	58	219	186	203	27	40	34	3.0	3.1	3.1	3.0	3.1	3.1
	C_8	6792	2674	4733	60	55	58	215	175	195	11	10	11	2.4	2.1	2.3	2.7	2.8	2.8
	C_{12}	6891	2950	4920	58	52	55	204	180	192	3	5	4	1.2	1.9	1.6	1.9	2.4	2.2
LSD (5%)		562	168	–	0.5	1.3	–	11	8.5	–	9.1	15.4	–	0.4	0.4	–	0.4	0.4	–
CV		9.3	6.6	–	0.9	2.7	–	5.4	5.1	–	44.2	48.9	–	15.2	15.4	–	16.1	15.2	–
Temp. x trop. QPM (dent)	C_0	4416	2635	3525	61	54	58	233	194	214	28	94	61	4.4	4.5	4.5	4.0	4.1	4.1
	C_4	4391	2763	3577	60	53	57	223	189	206	10	40	25	3.1	3.0	3.1	3.1	3.2	3.2
	C_8	4350	2718	3534	59	53	56	215	179	197	4	18	11	2.0	2.5	2.3	2.4	2.9	2.6
	C_{12}	4408	2955	3681	58	52	55	200	174	187	4	18	11	1.9	2.1	2.0	2.2	2.3	2.3
LSD (.05)		312	303	–	0.6	1.2	–	9.6	11.4	–	6.5	12.5	–	0.6	0.4	–	0.4	0.4	–
CV		7.7	11.9	–	1.2	2.4	–	4.8	6.8	–	61.5	32.1	–	22.5	15.8	–	15.9	13.6	–
Temp. white QPM	C_0	4421	2469	3445	58	51	55	225	183	204	15	53	34	3.4	3.9	3.7	3.1	3.9	3.5
	C_2	4393	2935	3664	58	52	55	218	188	203	7	43	25	2.4	2.7	2.6	2.7	3.2	3.0
	C_3	4370	2893	3631	57	51	54	210	179	195	4	39	22	2.1	2.6	2.4	2.2	2.9	2.6
	C_5	4540	2798	3669	57	52	55	208	176	192	3	17	10	1.8	2.0	1.9	2.3	2.3	2.3
LSD (.05)		295	274	–	0.6	1.4	–	7.6	13.2	–	4.0	18.6	–	0.4	0.5	–	0.4	0.5	–
CV		7.3	10.8	–	1.1	3.1	–	3.9	7.9	–	59.0	53.6	–	19.9	18.2	–	16.2	18.7	–

[a] 1 - 5 scoring scale (1 = excellent, 5 = poor)

Table 8. Relative frequency of modified kernels in different cycles of selection of four tropical QPM gene pools

Gene pool	Cycle	Score,[a] relative frequency of modified kernels 1	2	3 (%)	4	5
White flint QPM	C_0	2.2	12.9	30.6	23.9	30.3
	C_9	15.0	49.7	30.7	4.5	0.1
White dent QPM	C_0	1.4	16.1	32.9	25.7	23.8
	C_9	11.6	57.6	25.8	4.7	0.3
Yellow flint QPM	C_0	2.3	19.6	42.4	29.1	6.7
	C_9	6.6	47.3	40.7	5.2	0.2
Yellow dent QPM	C_0	2.3	18.5	35.2	35.3	8.6
	C_9	8.0	46.5	37.7	7.7	0.3

[a] 1 - 5 scoring scale:
1 = Completely modified
2 = 75% modified
3 = 50% modified
4 = 25% modified
5 = 0 % modified

Table 9. Protein, lysine and tryptophan content in the endosperm of four QPM populations through different cycles of selection

Population	Cycle	Protein (%)	Tryptophan (% of protein)	Lysine (% of protein)
Yellow QPM	C_0	8.0	0.78	2.9
	C_2	8.4	0.67	2.7
	C_4	8.6	0.77	2.9
	C_6	8.0	0.75	2.9
PD (MS)6 QPM	C_0	8.5	0.78	2.5
	C_2	9.1	0.75	2.6
	C_4	8.8	0.78	2.6
Temperate x tropical QPM	C_0	8.0	0.66	3.2
	C_2	8.0	0.68	2.8
	C_4	8.6	0.74	2.9
	C_6	8.1	0.74	2.8
	C_8	8.0	0.68	2.9
White QPM gene pool	C_0	8.5	0.85	3.4
	C_2	8.5	0.85	2.8
	C_4	8.4	0.74	2.6
	C_6	7.8	0.74	2.9
	C_8	7.8	0.74	2.7

Table 10. Distribution of progeny and experimental variety trials, 1980 to 1982

Trial no.	No. of entries	Number of sets distributed							
		South America	Central America	Caribbean	Mexico	Africa	Asia	Others	Total
1980									
IPTT-38	256	1	3	–	1	1	–	–	6
EVT-15A	18	13	7	5	5	24	9	–	63
EVT-15B	13	3	1	–	6	14	6	1	31
ELVT-19	15	10	8	2	4	28	5	–	57
1981									
IPTT-40	256	–	2	–	1	2	1	–	6
IPTT-41	256	1	–	–	1	–	3	–	5
QPMT-11A	12	14	14	8	9	39	15	1	100
QPMT-11B	12	10	5	–	1	24	12	1	53
1982									
QPMT-11B	11	–	–	–	–	–	–	–	–
EVT-15A	15	–	–	–	–	–	–	–	–

Table 11. Mean grain yield and other agronomic traits of families used in the formation of experimental varieties on the basis of 1981 data

Pop. no.	Name	Experimental variety	Grain yield (kg/ha)			% superiority of sel. fam. over		Days to flower		Plant height (cm)	
			Pop. mean	Sel. fam. mean	Check mean	Pop. mean	Check mean	Pop. mean	Sel. mean	Pop. mean	Sel. mean
40	White QPM	San Jeronimo 8140	7289	8898	6412	22.1	38.8	66	66	221	219
		Poza Rica 8140	5164	6284	5028	21.7	20.0	55	55	209	202
		Los Baños 8140	4249	5489	2833	22.6	93.7	54	55	211	213
		Across 8140	5586	6555	4757	17.3	37.8	58	59	212	217
41	Templado Amarillo QPM	Tlaltizapan 8141	8717	10500	9280	20.4	13.1	56	57	196	200
		Antalya 8141	7613	9286	6153	22.0	50.9	56	55	231	239
		Antalya (1) 8141	7613	10658	6153	40.0	73.2	56	57	245	231
		Islamabad (1) 8141	3985	4703	3375	18.0	39.3	57	55	187	191

Table 12. Mean performance of full-sib families across two locations in six QPM populations for yield and other characters, 1980B

Population	No. of families		Grain yield (kg/ha)		Selection differential (%)	Days to silk		Ear height (cm)		Endosperm modification score[a]		Ear aspect score[a]	
	Tested	Selected	Tested	Selected		Tested	Selected	Tested	Selected	Tested	Selected	Tested	Selected
Amar. Subtrop. QPM	236	86	4335	4516	4.2	55	55	96	96	2.0	1.8	2.9	2.6
Amar. Bajio QPM	130	59	4136	4366	5.6	55	55	95	95	2.0	1.7	2.6	2.5
Pool 34 QPM	188	70	3784	4113	8.7	55	55	92	93	2.0	1.7	2.9	2.6
La Posta QPM	219	69	3434	3748	9.1	58	58	113	114	2.3	2.1	2.7	2.4
Late white dent QPM	192	50	3527	3747	6.2	57	57	112	114	2.2	1.9	2.6	2.3
Pool 23 QPM	221	71	2810	3074	9.4	56	56	112	113	2.4	2.2	3.0	2.7

[a] 1 - 5 scoring scale (1 = excellent, 5 = poor)

Table 13. Oil levels in different cycles of selection of two QPM materials being selected for high oil content

Material	Cycle of selection	No. families analyzed	Range in oil content (%)	Mean oil content (%)
Temp. x trop. QPM (dent)	C_0	525	2.4 - 6.6	4.29
	C_1	222	3.2 - 6.3	4.64
	C_2	237	3.2 - 7.2	4.95
	C_3	338	3.7 - 6.7	5.21
White dent QPM	C_0	305	2.0 - 6.7	3.50
	C_1	560	3.0 - 6.6	4.62
	C_2	727	3.2 - 6.9	4.78
	C_3	465	3.0 - 7.9	4.95

Table 14. Comparison of normal materials and their QPM versions for yield and other agronomic traits

Material	Yield (kg/ha)[a]			Ear height (cm)		Days to 50% silking		Ear rot (%)	
	Normal	QPM	QPM as % of normal	Normal	QPM	Normal	QPM	Normal	QPM
Tuxpeño-1	6187	6152	99.4	111	110	61	60	2.2	5.4
Mezcla Tropical Blanca	6598	5593	84.8	119	111	61	59	3.3	4.2
Blanco Cristalino-1	6377	5538	86.8	113	114	58	58	2.9	3.4
Mix. 1-Col. Gpo.1 ETO	6117	5681	92.9	107	105	60	58	2.9	4.5
Mezcla Amarilla	5431	5237	96.4	103	106	58	58	2.9	5.7
Amarillo Dentado	5351	5230	97.7	125	110	61	57	2.5	3.2
Tuxpeño Caribe	6393	5903	92.3	117	115	61	58	2.5	4.2
Ant. Rep. Dominicana	5351	5080	94.9	100	112	56	57	2.3	3.7
La Posta	6470	5903	91.2	131	122	62	59	3.1	4.0
Pool 23	6184	5659	91.5	115	120	59	57	4.0	4.0

[a] Pooled over years and locations

Table 15. Performance of QPM in 30 selected locations, EVT-15A, 1980

Location	Best check	Yield (t/ha)	Best QPM	% yield of best check
Bolivia-Iboperenda	Mez. Trop. Blanca	7.7	Ferke 7940	99
Brazil-Sete Lagoas	CMS-05	6.9	Ferke 7940/1	113
Brazil-Guaira	ESALQ-VDZ-02	4.6	Poza Rica 7940	139
Ecuador-Pichilingue	Pichilingue 504	5.6	Poza Rica 7940	107
Venezuela-Durigua	Local check	3.1	Across 7740	127
Panama-Tocumen	Tocumen 7428	4.2	Poza Rica 7940	112
Panama Chiriqui	Tocumen 7428	4.8	Guanacaste 7940	111
Panama-Rio Hato	Tocumen 7428	5.3	Ferke 7940	93
Mexico-Poza Rica	Poza Rica 7643	5.7	Guanacaste 7940	98
Mexico-Cd. Obregon	H150	7.1	Ferke 7940	96
Ghana-Kwadaso	Opaque-2 Comp.	3.7	Poza Rica 7940	111
Ivory Coast-Ferkessedougou	IRAT81	5.8	Ferke 7940	92
Malawi-Bunmbwe	Local check	7.5	La Posta HEo_2-RSF[a/]	78
Mali-Sotuba	IRAT85	3.9	Guanacaste 7940	127
Mozambique-Umbeluzi	PR7740-o_2	2.3	Ferke 7940/1	138
Mozambique-Nampula	SR52	3.8	Across 7839	95
Rep. S. Africa-Potchefstroom	N06124o_2	7.1	Across 7740	91
Zaire-Kaniama	Kasai I	6.9	Obregon 7940	101
Bangladesh-Jessore	J1	9.3	Guanacaste 7940	108
Burma-Yezin	Indonesian Early	4.1	Poza Rica 7940	141
India-Varanasi	E.H. 400175	4.2	Guanacaste 7940	103
Philippines-Karaan	Local check	2.6	Guanacaste 7940	137
Nepal-Rampur	White Flint HEo_2	8.0	Poza Rica 7940	110
Thailand-Suwan	Suwan 1 C_7	7.8	Ferke 7940	81
Peru-Moyobamba	PM701	4.9	Ferke 7940	117
Peru-Satipo	PM701	5.8	Poza Rica 7938[a/]	72
Surinam-Tijgerkreek	San Andres 7528/1	3.4	Ferke 7940	165
Ethiopia-Alemaya	CA5 (M)	6.7	Across 7740[b/]	150
Nigeria-Onne	TZPB	2.8	Obregon 7940	115
Somalia-Afgoi	Godey	4.8	Ferke 7940	122

a/ Days to silk of best QPM is 7 or more days earlier than best check
b/ Days to silk of best QPM is 8 days later than best check

Table 16. Performance of QPM in 16 selected locations, EVT-15B, 1980

Location	Best check	Yield (t/ha)	Best QPM	% yield of best check
Argentina-Pergamino	R-3 Compuesto Ilo_2	7.7	Amar. Subtr. HEo_2-RSF	90
Bolivia-Iboperenda	Suwan 1	8.6	Obregon 7941	91
Ecuador-Pichilingue	INIAP 525	5.2	San Jeronimo 7941/1	94
Guatemala-San Jeronimo	ICTA B-1	7.5	San Jeronimo 7941/1[a/]	97
Mexico-Cd. Obregon	H510	8.1	Obregon 7941[a/]	73
Mexico-Tlaltizapan	H412	9.0	Temp. x Trop. HEo_2	95
Burundi-Mosso	(GP54 x SR52)	5.2	San Jeronimo 7941/1	112
Malawi-Chitedze	CCC	10.4	Obregon 7941[a/]	76
Malawi-Ngabu	PNR95	6.0	Amar. Bajio x Maices	73
Mozambique-Liona	$PR7740o_2$	4.3	Temp. x Trop. HEo_2	129
Mozambique-Mutuali	$PR7741o_2$	4.2	Obregon 7941	118
Rep. S. Africa-Potchefstroom	SX16	7.0	Across 7741	74
India-Godhra	Ganga-5	5.0	TW HEo_2 · RSF[a/]	105
Saudi Arabia - Hofuf	Tainan no. 5	6.7	Across 7741[b/]	116
Turkey-Antalya	NKPX616	6.8	TW HEo_2 · RSF	101
Turkey-Izmir	NKPX616	8.4	Amar. Subtr. HEo_2 · RSF[a/]	86

[a/] Days to silk of best QPM is 7 or more days earlier than best check
[b/] Days to silk of best QPM is 8 days later than best check

Table 17. Performance of QPM in 26 selected locations, ELVT-19, 1980

Location	Best check	Yield (t/ha)	Best QPM	% yield of best check
Bolivia-Sta. Cruz	Suwan 1	7.7	Across 7740	100
Bolivia-Iboperenda	Tuxpeño x Opaque-2	7.4	Across 7740	110
Ecuador-Pichilingue	INIAP 526	6.3	Across 7740	98
Venezuela-Acarigua	H. Obregon	2.9	Across 7740	136
Costa Rica-Alajuela	B666	6.7	Bl. Crist. HEo_2-RSF[a]	97
Guatemala-San Jeronimo	Comp. 2	5.1	La Posta HEo_2-RSF	101
Panama-Tocumen	Tocumen 742B	3.7	White HEo_2-RSF	126
Panama-Chiriqui	Tocumen P.B.	5.1	La Posta HEo_2-RSF	94
Mexico- Poza Rica	Across 7728	6.5	Ilonga 7740	78
Mexico-Cd. Obregon	H452	8.2	Across 7740	87
Mexico-Los Mochis	NL H5	6.0	Ilonga 7740	100
Mexico-La Huerta (Jal.)	Local check	3.7	Across 7740	133
Burundi-Imba	(GP54xSR52)	5.3	Across 7740	123
Egypt-Sakha	Comp. 5	8.7	La Posta HEo_2-RSF	88
Ghana-Kwadaso	Comp. W	3.9	WF HEo_2-RSF[a]	111
Ivory Coast-Bouake	Poza Rica 7429	4.7	La Posta HEo_2-RSF	114
Malawi-Chitala	PNR95	5.5	Ilonga 7740	93
Malawi-Mbawa	PNR95	7.8	Across 7740	77
Rep. S. Africa-Potchefstroom	$NO6124o_2$	6.1	Across 7740	93
Sierra Leone-Njala	Local check	3.5	La Posta HEo_2-RSF	122
Zaire-Kaniama	Kasai E	6.2	Bl. Crist. HEo_2-RSF	94
India-Delhi	Local check	2.8	White HEo_2-RSF	114
India-Pantnagar	Ganga-2	6.5	La Posta HEo_2-RSF	91
Thailand-Suwan	Suwan 1 C_7	7.8	La Posta HEo_2-RSF	76
Peru-Moyobamba	PMC747	5.3	Tux. Caribe HEo_2-RSF	118
Peru-Satipo	PM701	6.3	Mez. Tr. Bl. HEo_2-RSF[a]	85

[a] Days to silk of best QPM is 9 or more days earlier than best check

Table 18. Performance of QPM in 17 selected locations, QPMT-11A, 1981

Location	Best check	Yield (t/ha)	Best QPM	% yield of best check
Costa Rica-Alajuela	Tico H_4	4485	Across 7740 RE, Guanacaste 7940, Tuxpeño-1 QPM	104, 101, 96
Guatemala-Jutiapa	Local	4585	Guanacaste 7940, Tuxpeño-1 QPM	136, 116
Guatemala-La Maquina	HB47 (H)	4559	White BU Pool QPM, Guanacaste 7940, Tuxpeño-1 QPM	109, 106, 100
Honduras-La Cieba	Check 1	3832	Amarillo Dentado QPM, Guanacaste 7940	100, 88
Nicaragua-El Plantel	La Maquina 7422	6095	Ferke (1) 7940, Tuxpeño-1 QPM	96, 93
Panama-Guarare	Pioneer X-306B	4353	White BU Pool QPM, Across 7839	91, 87
Panama-Rio Hato	Tocumen Planta Baja	4387	Tuxpeño-1 QPM, Guanacaste 7940, Across 7839	115, 113, 102
Panama-Tocumen	Tocumen 7428	5253	Guanacaste 7940, Amarillo Dentado QPM	92, 87
Mexico-Cd. Obregon	Poza Rica 7822	4804	Pool 23 QPM	88
Mexico-Cd. Obregon	Poza Rica 7822	4529	Across 7740 RE, Tuxpeño-1 QPM	114, 105
Mexico-Poza Rica	Population 49 RSF	6705	Guanacaste 7940	92
Mexico-Jalisco, Nayarit	Criollo Car. Puerto	3661	White BU Pool QPM, Tuxpeño-1 QPM	118, 117
Ethiopia-Nazareth	Shaie	3732	Across 7839, Pool 23 QPM, Guanacaste 7940	118, 114, 110
Upper Volta-Farako-Ba	IRAT100	3452	Across 7740, Pool 23, White BU Pool QPM	109, 108, 104
Senegal-Nioro	HVB1	3643	Ferke (1) 7940, Guanacaste 7940, Tuxpeño-1 QPM	109, 104, 101
India-Delhi	EH400175	6243	Amarillo Dentado QPM	88
Thailand-Suwan	Suwan 1 (s) C_7	6897	Tuxpeño-1 QPM, Guanacaste 7940	83, 83

Table 19. Performance of QPM in 14 selected locations, QPMT-11B, 1981

Location	Best check	Yield (t/ha)	Best QPM	% yield of best check
Brazil-Londrina	AG301	5653	San Jeronimo (1) 7941	81
Guatemala-San Jeronimo	HA44	8334	San Jeronimo (1) 7941	94
Mexico-Tlaltizapan	Across 7845	7841	San Jeronimo (1) 7941	105
			Temperate White QPM	102
Egypt-Nuberia	Giza-2	11273	Temperate White QPM	85
Egypt-Sakha	Giza-2	3157	Amarillo Bajio x Maices Argentina QPM	128
			Temperate White QPM	120
Ethiopia-Nazareth	Shaie	4472	San Jeronimo (1) 7941	136
			Amarillo Bajio x Maices Argentina QPM	135
			Temperate White QPM	129
Morocco-Bouladuane	P586	4727	Amarillo x Maices Argentina QPM	121
			Amarillo Subtropical QPM	118
			Temperate White QPM	116
Pakistan-Islamabad	Local check 3	2754	Amarillo Subtropical QPM	144
			Temperate White QPM	116
Pakistan-Yousafwala	Sultan	7899	Across 7741 (RE)	89
Turkey-Adapazari	ADA	11045	Temperate White QPM	89
Turkey-Antalya	PX525	7603	Amarillo Bajio x Maices Argentina QPM	115
			Amarillo Subtropical QPM	112
Turkey-Izmar (2)	Demirday	5414	Obregon 7941	124
			Amarillo Subtropical	118
Paraguay-Caacupe	Venezuela-1	2643	Obregon 7941	77
Panama-Guarare	Across 7728	3558	Temperate White QPM	82

Special Projects

CIMMYT's maize program is currently conducting several special research projects for testing new ideas and techniques. These projects are special in the sense that they are distinct from, but relevant to, the general maize improvement program. In these projects, research activities are usually confined to one or a few population(s), and conclusions reached may ultimately influence the improvement priorities and methodologies of the maize program as a whole. Three major research projects, selection for drought tolerance, early maturity, and reduced plant height for greater grain yield efficiency, are summarized here.

Selection for drought tolerance

In tropical environments, periodic drought is caused by irregular rainfall distribution and is intensified by soils with low water-holding capacity; such drought causes sizable reductions in maize yields. Periodic drought may take place any time in the growing season; that occurring at time of planting, floral initiation, silking, and grain filling is probably the most severe.

The best way to reduce the effects of drought on maize is to minimize the damage caused by low moisture availability through the manipulation of genotype maturity and planting date. However, large areas of maize grown in the tropics are affected by drought which occurs at silking and early grain filling, and such drought cannot be totally avoided by this means. Therefore, in 1976, a project was begun by CIMMYT for improving tolerance to drought which occurs at the critical phases of plant development. In this project, drought escape mechanisms (genotype maturity or planting date) have not been considered.

The population Tuxpeño-1 has been used as a base material in the study, as it has the capacity to produce reasonably good yields under a wide range of moisture conditions. For population improvement, full-sib recurrent selection has been used. In each cycle of selection, 250 full-sib families were evaluated with six checks in two replications in a simple lattice design (16 x 16) in the dry, winter cycle at Tlaltizapan, Mexico, under nonstress, semi-stress and stress conditions. The nonstress treatment was that of adequate irrigation for normal growth; in the semi-stress treatment, there was adequate irrigation until about two weeks before anthesis. In the stress treatment, irrigation water was applied only at germination, if necessary.

In the winter cycle, all of the 250 full-sib families were improved at Poza Rica. For improvement, plants were selected on the basis of height, plant type, leaf angle, synchronization of pollen shed and silking, and other agronomic characters. At anthesis, plant-to-plant crosses were made among the selected plants within a family. In each cycle of selection, 50 to 60 families which showed good yield performance across the three moisture conditions, as well as good morphophysiological characters, e.g., plant height, leaf angle, relative rate of leaf elongation, canopy temperature or crop-water stress index, synchronization of pollen shed, and silking, were selected. In the summer, these selected families were recombined at Poza Rica by making plant-to-plant crosses between selected plants of different families. At harvest, 250 full-sib ears were selected for the next cycle of selection.

A yield trial after three cycles of selection showed that grain yield increase under stress conditions was about 9 percent per cycle, while the yield level under nonstress conditions was maintained

CIMMYT scientist performs infra-red canopy temperature measurements as part of study on drought tolerance in maize

(Table 1). The yield increase was mainly due to a higher rate of conversion of accumulated dry matter to grain, i.e., a higher harvest index (Table 2).

Selection for early maturity

In tropical and subtropical maize-growing regions, early maturing varieties are desired since they offer a number of potential benefits to the farmers, e.g., flexibility in planting date under rainfed conditions, the opportunity for increasing cropping intensity, and flexibility for escaping the occasional drought that may occur at the beginning or the end of the season. Early-maturing varieties can also facilitate early land clearing, thus conserving soil moisture for the next crop. Earliness also makes possible the harvesting of the crop at an earlier date, when scarcity of food grain is common, as occurs among subsistence farmers in Africa, Asia and Latin America.

The problem of early-maturing varieties has always been the sacrifice in grain yield. Therefore, in 1975, CIMMYT undertook a program aimed at breeding and developing earlier maize varieties, without sacrificing grain yield, for the tropical and subtropical maize-growing areas of the world. For this purpose, a population called Compuesto Seleccion Precoz was formed. (For details its formation and the materials used, see CIMMYT's Report on Maize Improvement, 1978-79.)

A half-sib recurrent selection program has been undertaken in the population Compuesto Seleccion Precoz since 1976, and two cycles of selection have been completed each year in two locations, Poza Rica and Tlaltizapan, Mexico. In this selection procedure, 500 half-sib families are planted in a structure of 2 female:1 male; the male is the bulk of the superior families of the population. Each entry is planted in a 5-m row with standard row spacing of 0.75 m and plant-to-plant spacing of 0.33 m. Thus, a density of 43,600 plants/ha is maintained for the females; the density of the males is double that figure. The higher density in the male rows is used to select for tolerance to density pressure by eliminating the weak, lodged plants and the plants with poor synchronization of pollen shed and silking. These undesirable plants, together with the plants in the female rows, are detasseled before pollen-shed. In the male rows, when 70 percent of the plants have silked, all plants are detasseled and, at anthesis, early plants in the female rows are marked. Final selection is made from these plants. At both locations, the materials are harvested relatively early to aid in the visual separation of the drier ears from the superior plants previously selected for earliness. These ears are used for the continuation of the next cycle.

This population has undergone eight cycles of selection. Yield trials with different cycles of selection in Mexico have showed that days to silk have been reduced about half a day per cycle in summer (Table 3) and about one day per cycle in winter (Table 4). Grain yield has not been reduced significantly with increased earliness.

Selection for reduced height

In tropical maize, the efficiency of grain production relative to total dry matter accumulation is less than that of maize in temperate climates. Tropical maize plants are taller and produce a relatively greater proportion of total dry matter in the form of stems, leaves, and tassels, and less in grain; this appears to be one of the main factors for its low harvest index.

In the late 1960s, CIMMYT started a project aimed at breeding and developing plant types with greater partitioning of total dry matter to grain, and increased agronomic suitability for more intensive management, particularly in high-yielding, full-season materials. To achieve these objectives, recurrent selection has been done to reduce plant height of some CIMMYT materials.

Most CIMMYT maize populations now have generally acceptable plant height, yield potential, and standability. Many of these tropical lowland and subtropical populations, originally three to four meters tall, have been reduced to two meters in height. The few CIMMYT populations that are still tall are receiving selection pressure for reduced height, and several have responded dramatically to such pressure. Population 49, for example, which is based on Tuxpeño-1, is now less than two meters tall and has a grain-to-stover ratio of about 50:50, roughly that of US Corn Belt materials. Results of trials conducted on Tuxpeño-1 under experimental field conditions and farmers' field conditions are shown in Table 5, 6 and 7.

Table 1. Effect on grain yield after selection for various characters under irrigation and stress conditions, Tuxpeño stress conditions, Tuxpeño grown at optimum density, Tlaltizapan, 1981

Character	Cycle	Grain yield (kg/ha) Irrigation	Grain yield (kg/ha) Stress	Yield change/cycle (%/o of original) Irrigation	Yield change/cycle (%/o of original) Stress
Reduced height[a]	6	5276	1129		
	12	5358	1203	1.0	1.1
	15	5893	1718*	1.3	5.8
	18	6129	1570*	1.3	3.3
Reduced tassel	0[b]	5608	1213		
	6	6172	1673*	1.7	6.3
Reduced leaf	0[b]	5608	1213		
	5	6196	1468*	2.1	4.1
Drought resistance	0	5859	1224		
	3	6179	1572*	1.8	9.5
	EV[c]	6311	1647		
Pop. 21 (cycle 3)[d]	0[b]	5608	1213		
	3	6458	1315	5.0	2.8
LSD (P = 0.05)		899	433		
CV%/o		11.7	23.8		

[a] Planting dates arranged so all cycles flowered at or near (± 1-2 days) same time
[b] Best estimates of original cycle
[c] Experimental variety (4%/o selection intensity)
[d] Selected for yield stability and wider adaptation through international progeny testing system
* Difference from original cycle significant (preplanned F test) at P = 0.05

Table 2. Total dry matter, harvest index and ears per plant for various selections in Tuxpeño under irrigated and stress conditions, Tlaltizapan, 1981A

Character	Cycle	Total dry matter (kg/ha) Irrigated	Total dry matter (kg/ha) Stress	Harvest index Irrigated	Harvest index Stress	Ears/100 plants Stress
Reduced height[a]	6	13653	5408	34.0	15.1	56
	12	13637	5157	39.1	15.0	65
	15	12682	5719	42.9	25.6	85
	18	13043	5327	44.7	25.0	72
Reduced tassel	0[b]	13765	6112	39.5	15.7	58
	6	14409	6778	41.4	22.2	65
Reduced leaf	0[b]	13765	6112	39.5	15.7	58
	5	13200	5510	44.3	24.1	73

Table 2. (Cont'd)

Character	Cycle	Total dry matter (kg/ha) Irrigated	Total dry matter (kg/ha) Stress	Harvest index Irrigated	Harvest index Stress	Ears/100 plants Stress
Drought resistance	0	13894	6246	39.6	16.4	57
	3	14147	6807	38.3	20.9	65
	EV[c]	14544	7099	38.2	20.8	74
Pop. 21 (cycle 3)[d]	0	13765	6112	39.5	15.7	58
	3	14995	6147	40.3	15.7	56
LSD (P = 0.05)		N.S.	996	6.1	2.0	12.8
CV%		19.1	15.1	11.6	32.8	16 5

[a] Planting dates arranged so all cycles flowered at or near (± 2 days) same time
[b] Best estimates of original cycle
[c] Experimental variety (4% family selection)
[d] Selected for yield, stability and wider adaptation through international progeny testing system

Table 3. Grain yield, grain yield per day, optimum density, and maturity indices for materials being developed for early maturity when grown in summer at three locations in Mexico

Population	Cycle	Grain yield (kg/ha) Optimum density	Grain yield (kg/ha) 50,000 plants/ha	Grain yield per day ($g/m^2/day$)	Optimum density ($plants/m^2$)	Maturity Days to flower	Maturity Physiological maturity[a]
Compuesto	0	5635	5367	5.46	6.5	56.8	103.1
Seleccion Precoz	4	5476	5004	5.37	7.7	54.1	102.0
(selected for earliness)	8	5427	5195	5.42	7.5	52.6	100.1
Change per cycle (%)		−0.46	−0.41	−0.09	1.86	−0.93[c]	−0.36
Compuesto	0	4330	3521	4.50	8.5	52.0	96.2
Seleccion Precoz (selected for yield)[b]	1	4830	4454	4.91	8.1	52.8	98.3
Change per cycle (%)		11.5	26.5	9.1	−4.7	1.5	2.2
LSD (P = 0.05)		414	402	0.40	1.2	0.8	2.9
CV%		9.0	9.6	10.0	18.2	1.4	8.7

[a] From two locations, Poza Rica and Tlaltizapan
[b] 4% selection pressure
[c] Equivalent to a reduction of 0.5 days per cycle

Table 4. Grain yield, grain yield per day, optimum density, and maturity indices for materials being developed for early maturity when grown in winter at two locations in Mexico

Population	Cycle	Grain yield (kg/ha) Optimum density	Grain yield (kg/ha) 50,000 plants/ha	Grain yield per day ($g/m^2/day$)	Optimum density ($plants/m^2$)	Maturity Days to flower	Maturity Physiological maturity[a/]
Compuesto	0	5574	5173	3.98	7.8	87.5	140.2
Seleccion Precoz	4	5763	5080	4.16	8.8	79.7	138.5
(selected for earliness)	8	5708	5066	4.28	9.1	77.2	133.4
Change per cycle (%)		0.30	−0.26	0.94	2.05	−1.48[b/]	−0.80
Componentes Precoces	0	4847	3789	3.83	10.8	72.0	126.6
(selected for yield)	1	4918	4109	3.85	8.0	75.2	127.6
Change per cycle (%)		1.5	8.4	0.6	−26.0	4.5	0.8
LSD (P = 0.05)		414	402	0.4	1.2	0.8	2.9
CV%		9.0	9.6	10.0	18.2	1.4	8.7

a/ Data for Tlaltizapan only, adjusted for comparison with other data
b/ Equivalent to a reduction of 1.3 days per cycle

Table 5. Plant height, grain yield, lodging, and optimum planting density for various cycles of selection for reduced plant height in Tuxpeño-1 grown at three locations, Poza Rica, Obregon and Tlaltizapan, Mexico

Cycle of selection	Plant height (cm)	Grain yield (t/ha) Optimum density	Grain yield (t/ha) 50,000 plants/ha	Lodging (%)	Optimum density ($plants/m^2$)
0	282	3.17	3.13	49	4.6
6	218	4.29	4.24	9	5.4
9	210	4.48	4.31	10	5.6
12	202	4.93	4.71	6	5.6
15	179	5.40	5.03	5	6.5
LSD (P = 0.05)	7	0.32	0.36	12	1.2

Table 6. Plant height, grain yield, leaf area index, total dry matter, and harvest index for various cycles of selection for reduced plant height in Tuxpeño-1 grown at or near optimum density, Poza Rica and Tlaltizapan, Mexico[a]

Cycle of selection	Plant height (cm)	Grain yield (t/ha)	Leaf area index	Total dry matter (above ground) (t/ha)	Harvest index
0	273	4.05	4.67	14.94	0.30
6	211	5.54	4.49	14.75	0.38
9	203	5.67	4.41	15.32	0.39
12	196	6.18	4.49	15.37	0.41
15	173	6.73	4.26	15.12	0.46
LSD (P = 0.05)	10	0.41	0.45	1.84	0.05

[a] Data are means for 2 years

Table 7. Grain yield and optimum density for various cycles of selection for reduced plant height in Tuxpeño-1 grown under farmer conditions with different management levels at five locations in Mexico

Cycle	Grain yield (t/ha)			Optimum density for recommended management (plant/m^2)
	Recommended management	Poor weed control	Low nitrogen level	
0	3.34	2.23	2.47	4.2
6	4.16	2.80	3.00	4.5
12	4.34	2.67	2.87	5.1
15	5.02	3.27	3.30	5.8
18	4.46	2.97	2.76	5.8
Change per cycle (%)[a]	2.94	2.44	1.75	2.5

[a] For cycles 0 to 15

Wide Crosses

The aim of the wide-cross program is to investigate the possibility of synthesizing wide crosses with maize and to obtain more information about their production and use. A wide cross with maize, as defined by the program, involves crossing maize with an alien genera in order to obtain a self-sterile F_1 which normally results from the fusion of the haploid gametes derived from both parents. Attempts are then made to achieve successive generations, utilizing techniques such as backcrossing and colchicine doubling in order to obtain maize plants with some alien genetic material. Research into the hybridization of maize with sorghum and *Tripsacum* continued in 1980-81.

Considerably fewer crosses were made between maize and sorghum and maize and *Tripsacum* during 1980-81 than in the period 1978-79. It was decided in 1980 that the CIMMYT Poza Rica station did not offer any particular environmental advantage for crossing maize and the alien genera. Thus, a decision was made to use only the Tlaltizapan (2 cycles per year) and El Batan (one cycle per year) stations for maize wide crosses, resulting in a lower number of crosses. In 1980, approximately 2,000 crosses were made between maize and *Tripsacum* and approximately 3,300 between maize and sorghum.

Emphasis was placed on cytology in 1981, in order to adapt existing techniques of chromosome identification to maize, sorghum, and *Tripsacum*. Standard cytology in most cases is sufficient to identify the parental species and hybrid where chromosome number is equal to the number expected. Chromosome banding techniques were used to determine chromosome identity in plants containing abnormal chromosome numbers and to verify the genome origin of chromosomes in the hybrid. In this respect, the N-banding technique did not produce differential staining of chromosomes.

Through wide-cross research, CIMMYT scientists hope to tap the potential of *Tripsacum* and other genera for improving the maize crop's disease and insect pest resistance and its tolerance to various environmental stresses

However, the C-banding technique produced bands on maize, sorghum, and *Tripsacum* chromosomes which allow the chromosomes of the genera to be differentiated. Figure 1 illustrates a C-banded preparation of a maize x *Tripsacum* hybrid; a formal, detailed description of this procedure will be published.

Wide crosses with maize often give rise to seeds that exhibit endosperm collapse, and this may result in embryo death before physiological maturity. It is therefore necessary to have a workable nutrient medium so that embryos may be excised and developed into seedlings in an artificial environment.

Thus, during 1981, about 40 percent of wide-cross research time was devoted to the development of improved media for embryo culture.

Four different media were, accordingly, tested for their ability to produce seedlings from sorghum and maize embryos. The four media used were MS (Murashige and Skoog), Taira (derived from MS), a modified Nirsh medium, and R1 (Miller's medium). All four media were successful in stimulating seedling development from embryos. However, R1 was superior in terms of seedling vigor. No gross morphological abnormalities were observed in control maize plants grown to maturity following embryo

Figure 1. Chromosome 46 of a maize x *Tripsacum* cross, F_1 generation (C-banded)

culture, even in plants derived from deliberately damaged embryos. At this stage in the program, it is felt that the media in use are satisfactory for the stimulation of seedling development from hybrid embryos.

Maize by *Tripsacum* Crosses

During 1980-81, approximately 3,600 crosses were made between maize and *Tripsacum*. In 1980, one hybrid was recovered from approximately 2,000 crosses. A small percentage of the developing seeds were sacrificed in order to establish a technique for the analysis of chromosome numbers at this early stage. In 1981, 1,600 crosses were made, and 27 plantlets were generated from mature seed resulting from these crosses; of these only 179 ears gave seed which matured without total endosperm collapse. A large percentage of the seed development was probably only stimulation of maternal tissue and, as such, completely collapsed before harvest. To date, germination has been attempted with only 60 percent of this mature seed and the resultant seedlings analyzed for chromosome constitution. Of the 27 plantlets isolated in 1981, 26 were hybrids having 10 maize and 36 tripsacum chromosomes. One plant was normal maize, although the seed phenotype that gave rise to this plant was not normal in appearance. Fourteen of these plantlets died after planting. The higher recovery from mature seed was due to removal of the seed coat during germination. This removal allowed better water uptake and coleoptile emergence. Some potential hybrids were lost due to experiments with other methods of germination. The remaining 40 percent of mature seed isolated in 1981 will be germinated using embryo culture.

To date, the most successful *Tripsacum* parent has been *Tripsacum dactyloides* 65-1234; only two other *Tripsacum* parents are being maintained as perennial hybrid combinations with maize.

Although only mature seeds containing endosperm were harvested in 1981, most of these seeds contained no embryo at time of harvest. Over 90 percent of these seeds, however, did have an indented endosperm showing the presumed position of the embryo before degeneration (Figure 2). It is therefore likely that embryo culture may not allow the recovery of all embryos produced in maize/*Tripsacum* crosses, as a percentage of the embryos may be genetically inviable. Further support for this probability was evidenced by the fact that only five seedlings were isolated from 96 maize/*Tripsacum* embryos grown on media and sampled over a range of time after pollination. Four of these seedlings died before transplanting, and the fifth died after transplanting. In the case of maize/maize, 98 percent of the embryos harvested over a range of time (9 to 15 days post-pollination) produced seedlings on the four types of media tested.

Research is continuing with maize/*Tripsacum* crosses in an attempt to achieve hybrids with other tripsacum parents, colchicine doubled amphiploids, and backcrossings with plants from the existing classical hybrids.

Maize by Sorghum Crosses

In 1980-81, approximately 5,800 crosses were made between maize and sorghum. In 1980, approximately 3,300 crosses were attempted. Most of the seeds that developed, however, were sacrificed in an unsuccessful attempt to obtain cytological evidence of hybrid formation.

In the first cycle of 1981, most of the seeds were allowed to go to maturity in order to check on endosperm development and the time period before seed collapse. No seeds reached maturity. During the second cycle of 1981, approximately 900 crosses were made between maize and sorghum and six plantlets developed from over 600 attempts at culturing of seed contents on four different media.

Three of the plantlets were normal maize and exhibited no morphological abnormalities. Two of the remaining plantlets died after producing a 1 to 2-mm shoot and no roots, and the remaining one died after producing two tiny roots and no shoot. During 1978-79, nine presumed hybrids resulted from 23,000 crosses; thus, the number of crosses made in 1981 was possibly too small to realize a hybrid.

Over 400 of the seed developments that were dissected for embryo culture were completely empty, while 70 developments consisted of a seed coat and a watery, jelly-like substance which was probably nucellar tissue. Twenty-five seeds, which were a little older, contained enlarged nucellar tissue, probably due to water uptake. However, no development of the embryo sac was observed. A further 11 seeds contained a granular endosperm which was not jelly-like, and one of these was observed to contain possible embryo development. However, this did not develop further on media.

Most of the development was felt to be stimulated maternal tissue. Research will continue in an attempt to isolate hybrid plants of maize/sorghum for cytological analysis.

Collaborative Wide-Cross Research

Collaborative research continued in association with the CIMMYT wide-cross program, its former unit head, and C.E. Green, University of Minnesota, T.B. Rice, Pfizer Genetics, Groton, Connecticut, and B.J. Reger, United States Department of Agriculture, Athens, Georgia.

Publications

Reger, B.J., and J. James. 1982. Observations of pollen germination and pollen tube growth of sorghum with maize and pearl millet. Crop Science 22:140-144.

Regional Programs

CIMMYT maize scientists, assigned to various maize-growing regions throughout the developing world, form strong ties among national collaborators within a region and with CIMMYT. This 1980-81 report presents, for the first time, a brief look at the activities of each regional program and notes progress for the period.

Eleven staff members have regional responsibilities in neighboring countries where maize either is, or has the potential to become, a major crop. In these regions, maize is grown under similar conditions and is exposed to similar diseases and insects. Regions include Central America and the Caribbean, the Andean countries, West Africa, the Mideast, and South and Southeast Asia.

CIMMYT scientists help to distribute and evaluate CIMMYT germplasm within the region. They encourage and assist national programs to develop production agronomy research programs which include on-farm research activities. On-farm research is undertaken to develop appropriate production recommendations for farmers. CIMMYT scientists also collaborate with national scientists in specific agronomic research activities.

Other objectives include the coordination of training activities within and outside the region, and workshops and field tours for regional scientists. In addition, the maize researchers carry out specific research activities for which the region is particularly well suited in order to benefit the worldwide network.

Central America and Caribbean Regional Program

The two CIMMYT maize scientists assigned to this area work with staff from six Central American and seven Caribbean countries of the region. Their efforts are directed toward strengthening the national programs and promoting a continuous germplasm and information exchange among breeders and production agronomists.

The years reported here were years of continued growth; new varieties (over 35) and hybrids were officially distributed, and grain yield per hectare increased dramatically in most of the areas where strong production programs were ongoing.

CIMMYT scientist (second from left) and coordinator of Guatemala's national maize program (far left) visiting the field of a farmer, who has planted 20 ha of a newly released variety derived from CIMMYT germplasm

Regional staff assisted in conducting international maize trials distributed to area countries. In addition, they aided in the assembly, distribution, and data evaluation of the PCCMCA (Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios) trials distributed throughout the region.

Land area planted to maize has increased in Guatemala, El Salvador, and Honduras. Improved varieties and hybrids developed by ICTA (Institute for Agricultural Sciences and Technology), based on CIMMYT germplasm, have increased grain yield production from 1.59 t/ha to 3.6 t/ha in Guatemala's lowland. Improved varieties developed in Honduras, combined with the use of production technologies, have contributed to a consistent grain production of 4.0 t/ha in the department of El Paraiso. Mean grain yields before the program initiated improvement activities were 1.2 t/ha. Similar results were obtained in the Valley of Olancho and the Valley of Sula in the northern part of Honduras.

Continued emphasis was given to breeding for earliness, greater corn stunt resistance, adaptation to conditions of drought stress, improved husk cover, and reduced ear rots. On-farm research continued to receive major program attention, with emphasis on weed control and minimum tillage.

Regional scientists continued to develop superior varieties in cooperation with CIMMYT. Families were selected from IPTT trials and recombined at CIMMYT's experiment stations to form experimental varieties.

Across-location analysis for the region was obtained for ELVT 18A and 18B from data collected in 1981. Five of the best-yielding varieties of EVT 18A grown in 14 locations are shown in Table 1. Also shown are the 5 best varieties among the 24 tested.

Corn stunt-resistant varieties are being developed in cooperation with Nicaragua and El Salvador. Downy mildew (DM) resistant varieties are being developed in Honduras. Tuxpeño-origin germplasm is reported to carry a reasonable level of gene frequency for DM resistance. A new inbred line with high combining ability has been derived from La Posta, Colima 14 (Tuxpeño 1) and a population derived from intercrossing all the best commercial varieties with DM resistance. This population also includes 60 CIMMYT inbred lines resistant to DM.

Andean Regional Program

CIMMYT's Andean Maize Region comprises Bolivia, Colombia, Ecuador, Peru, and Venezuela and covers about 4.7 million square kilometers. Around 2 million hectares are devoted to maize, with total annual production around 2.7 million tons. The region imports close to 1 million tons a year.

Because of its geography, altitude, and latitude, the Andean Region (AR) has a great diversity of climates. The AR can be divided, roughly, into three large ecological areas, the coastal plains, the jungle, and the highlands. (Each of these areas can, in turn, be subdivided according to rainfall pattern, altitude, type of soils, and so forth.) Because of these large ecological differences, a number of specific breeding and production programs have been implemented in the various countries. Thus, CIMMYT is currently collaborating with 21 maize-breeding programs, both official and private, and with 16 maize-production projects.

The main objective of one such program, the CIMMYT-CIAT Andean Region Maize Program (PRAM), is to cooperate with national programs in the development and validation of maize technology, and to constitute a link between the national programs and CIMMYT. Since CIMMYT's arrival in the region (1976-77), PRAM has helped strengthen the national programs and assumed countinuity of national program research.

Following are some highlights from the two major efforts in the region, maize breeding (highland and lowland) and on-farm research.

Highland Floury Maize Breeding

Maize in the Andean highlands (Colombia, Ecuador, Peru, and Bolivia) is the major staple cereal crop for the rural areas. Two types of maize varieties are predominant, floury and a special flinty type called morocho.

The Floury Maize Program was started in the 1977-78 crop season, in collaboration with Ecuador's National Institute of Agricultural Research (INIAP), and headquartered at Santa Catalina Experiment Station, at an altitude of 2650 to 3250 meters and about 14 km south of Quito, Ecuador.

To initiate the program, six highland gene pools, with a wide genetic variety of materials from the Andean zone and other parts of the world, were developed. These gene pools correspond in grain texture, type, color, agronomic characters, and maturity to the local highland Andean varieties. These gene pools will mainly serve the altitude ranges of mountain valleys and plateaus of about 2200 to 3600 meters.

Floury maize occupies the majority of the highland maize-producing areas. However, the proportion of floury to morocho varies from country to country. In Peru, floury maize has been extensively cultivated as a major cereal crop over hundreds of years. Consequently, considerable genetic diversity occurs there.

Agroclimate in the highlands
The tropical highlands of the Andean zone consitute a distinct agroclimate. Tropical lowland maize is not adapted above 1700 meters; highland maize types take over from that altitude and up to 3900 meters as, for example, near Lake Titicaca. However, the extreme altitude ranges are marginal production areas.

In the Andean zone, cool temperatures prevail. Mean temperatures in the warmer months are below 20°C. The growing period extends from 7 to 10 months, depending upon the region and varietal maturity period. Planting time is August to November south of the equator, and January through March north of equator. The area is mostly rainfed, but supplemental irrigation is available in mountain valleys.

Characteristics of Andean highland maize
Very few distinct floury maize races are grown at present. Many races have been hybridized, and racial mixtures (varieties often called *común*) are frequently cultivated in the region. Andean flint maize is called morocho (Spanish version of the original *muruchu* hard maize). Morocho types have a more or less soft floury endosperm surrounded by hard crystalline endosperm. The central floury portion can be seen through the external endosperm. Morocho types are used as meal maize, since the grain is easily crushed, unlike the popcorn and corneous flint types of the lowland and temperate zones. The floury and morocho varieties are presumably genetically interrelated, since both kernel types are found in the different races existing in the region.

Some Andean floury varieties (Ancashino, Shajatu, San Geronimo, etc.) have rather loose, very soft floury endosperm. Cacahuacintle has compact floury endosperm. Morocho varieties have differential degrees of outer endosperm hardness. Sabanero (morocho) and the morocho from northern Ecuador have somewhat harder endosperm texture than Zhima from southern Ecuador, and Amarillo de Oro and Amarillo Calca from Peru. Cuzco Cristalino Amarillo has varying degrees of endosperm flintiness; the higher altitude collections have more flinty yellow endosperm texture (Grobman *et al.*, 1980, Races of Maize in Peru, p. 244). The relative endosperm hardness in floury and morocho varieties is probably genetically controlled by a complex of modifier factors. Another kernel characteristic of floury and morocho maize is the absence of glume attachment to the base of the kernel when shelled. This is especially desired for whole, toasted grains (tostado). The floral structure of typical floury and morocho maize is sessile.

Kernel color is most conspicuous in floury maize. The anthocyanins and related pigments are mostly responsible for pericarp and aleuron color. The central white endosperm is predominant in floury maize, even though pericarp and aleuron pigments exist. Yellow floury corns of Chillo, Mishca, and Sabanero often have their yellow pigments confined to the aleuron layer, which tends to fade out under the sun. The central yellow endosperm color gene (Y) has been introduced into gene pools 3 and 4. It expresses intense yellow endosperm color by the presence of carotenoid pigments. This yellow floury endosperm character of pools 3 and 4 will be tested for acceptance by the farmers. Morocho has both yellow and white endosperm types.

Kernel shape and size varies considerably. Very large—long, wide, and thick—kernels are characteristic of Cuzco Gigante. Chillo has a large kernel, slightly pointed and very thick; San Geronimo and Sabanero have thick and rounded kernels of intermediate size. These races represent the kernel phenotypes for which the floury gene pools 1, 2, 3, and 4 are being improved. Early pools 1 and 3 are being selected only for San Geronimo and Sabanero kernel phenotype, while pools 2 and 4 are being selected for Cuzco and Chillo types, respectively. Floury-type kernel density will become important in considering compactness of endosperm in relation to kernel size. Larger kernel size is generally preferred by the farmer. Morocho has kernels of intermediate size with Cuzco and Sabanero kernel shapes.

Development and improvement of highland gene pools

Andean highland maize has had limited germplasm introgression from other parts of the world, although a few exotic varieties are grown by farmers. Improvement of local maize for broader adaptation, higher yield, earlier maturity, and disease and insect resistance is the primary breeding objective. A breeding strategy to broaden the genetic base of floury and morocho maize has been adopted, since local maize varieties are often specifically adapted to the topographical conditions where the races originated. In recent years, considerable yield reduction has occurred in the Andean highlands from ear rots and insect damage. Ear rots are caused by *Fusarium graminearum, Diplodia maydis,* and *Cephalosporium acremonium*.

Insect ear damage by *Heliothis zea* and *Euxesta eluta* often leads to secondary ear rot infections. Control measures are also needed for cutworm (*Agrotis ipsilon*), fall armyworm (*Spodoptera frugiperda*), and stored-grain insects (*Pagiocerus fiorii*). Foliar and stalk diseases are *Puccinia sorghi, Cercospora maydis, Helminthosporium turcicum, Phyllachora maydis*, fine stripe virus, *Fusarium moniliforme, Diplodia maydis,* and *Erwinia* spp.

Gene pools have been formed by incorporating germplasm for wide adaptation, kernel phenotype (size, shape, texture, and color), and maturity (early and late). For the establishment of gene pools, with wide genetic bases, cross pollination was made among germplasm sources of Andean countries, previous CIMMYT highland pools, and other materials being improved for the highland areas. The highland materials from Mexico contribute adaptation and resistance to main foliar diseases (late blight and rust), but also contribute to tillering and a poor root system; the Andean materials, on the other hand, have good root systems and single stalks. A half-sib recombination block was used. The male and female components, for each pool, are given in Figure 1. Care was taken to include the main germplasm of the desired kernel phenotype for each pool, in order to ensure the occurrence of the desirable recombinants through random genetic mixing. More germplasm, as it is identified, is periodically being added to the respective gene pools. In each planting cycle, gene pools are planted at CIMMYT highlands stations (one or two sites), and in Ecuador at the Santa Catalina Experiment Station (one or two sites). Superior selections from both Mexico and Ecuador constitute the male composites for the next cycle of half-sib planting at these sites.

Figure 1. Establishment of highland gene pools

Pool	Contribution of Germplasm	
	Female entries[a]	Male or male and female entries[a]
Pool 1, 1978-79 White early floury	Early white floury, flint and dent- Peru, Bolivia, Ecuador, CIMMYT Sabanero, Chuncula, Huancavelicano, Ancashino, Cuzco, Paro and others	HEWFL, HIWFL, Comp. G.G.[b] - CIMMYT Cacahuacintle, San Geronimo, Ancho and others ♂♀
Pool 2, 1978-79 White late floury	Late white floury, flint and dent - Peru, Bolivia, Ecuador, Colombia, CIMMYT Cacahuacintle, San Geronimo, Ancho, Sabanero Blanco and others	Cuzco Gigante - Peru Blanco Harinoso - Ecuador Cuzco Gigante, Cuzco and others ♂

Pool 3, 1977-78 Yellow early floury	Early floury, flint and dent - Peru, Bolivia, Colombia, Ecuador, CIMMYT Piscorunto, Terciopelo, Amarillo Ancash, Kellu Morado, Paro, Rojo Huarotambo and others	Comp. Amarillo Harinuso Precoz - CIMMYT Cacahuacintle, Krug, Cuzco, Mishca, Chillo, Sabanero Amarillo, Pachia, Hulicaparu and others ♂♀
Pool 4, 1978-79 Yellow late floury	Late floury, flint and dent - Colombia, Peru, Ecuador, Bolivia, CIMMYT Sabanero Amarillo, Huandango, Mishca, Marañon, Cacao, Umutu, Ancashino Tardio, Cacahuacintle, Krug, Cuzco, Pachia, Hulicaparu, Ancho and others	Collections of Chillo - Ecuador Chillo ♂♀
Pool 5, 1979-80 White early morocho	Early white morocho, flint, dent and floury - Colombia, Peru, Bolivia, Ecuador, CIMMYT Uchuquillo, Sabanero, Conico, Chalqueño, Titicaca, Gaspe, Ancho and others	INIAP 151, INIAP 153, Morocho, Ibarreño - Ecuador Zhima, Morocho Blanco and Ibarreño ♂
Pool 6, 1977-78 Yellow early morocho	Early morocho, flint, dent and floury - Peru, Ecuador, Bolivia, Colombia, CIMMYT Cuzco Cristalino, Ayacuchano, Uchuquillo, Morocho, Amarillo de Oro, Aysuma, Pisankalla and others	HEYF, Comp. Precoz Amarillo Tipo Conico Grande - CIMMYT Sabanero x muy Precoz de Altura Sel. Amarillo - Ecuador Conico, Sabanero, Titicaca, Chihuahua, Krug, Chalqueño and others ♂♀
Pool 7, 1979 White late morocho Pool 8[c/] Yellow late morocho	Late morocho, flint, dent and floury - Andean countries, CIMMYT Morocho, Cajabambiño, Chalqueño, Krug and others	INIAP 176, 178, 151, 153 - Ecuador Mayceño - Guatemala Sabanero, Ibarreño, Zhima Montaña, San Marceño, Guatemalteco and others ♂♀

a/ Further detailed information on the entries is given in CIMMYT Report on Maize Improvement 1978-79

b/ HEWFL = highland early white floury, HIWFL = highland intermediate white floury, Comp. G.G. = Compuesto Gran Gigante

c/ White grains were separated out from Pool 7 to form Pool 8 in 1982

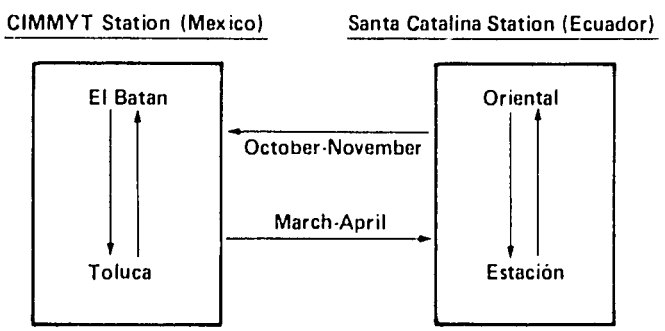
Note: In each square are given the varieties and composites, endosperm types and maize races involved

Figure 2 shows the sequence followed at these sites in each cycle of modified half-sib recurrent selection. Breeding for insect resistance (*Heliothis zea*) and ear rot (*Fusarium graminearum*) is carried out at CIMMYT, under artificial infestation and inoculation. Similar ear rot inoculation will also be implemented at the Santa Catalina Experiment Station.

The upper limit of number of days to silk for early pools (1, 3 and 6) is being set at 90 for the Oriental site of the Santa Catalina Station. For late pools (2, 4, 7 and 8), silking from 105 to 115 days after planting is being sought. In each cycle, data on days to silk at the Oriental site are used as a reference for other sites, since the Oriental site is planted first. Considerable variation in days to silk is observed in each pool. Late and early family crosses in the pool are facilitated by different dates of planting of male rows or by bulk hand pollination. At harvest, ears with desirable kernel characteristics are selected.

The CIMMYT El Batan site, in the Valley of Mexico, provides a good ear rot screening nursery. At Santa Catalina, most of the Andean highland maize can be successfully grown. El Batan and Santa Catalina locations are, therefore, instrumental in creating genetic recombinations for ear rot resistance and other desired agronomic characteristics. Undesirable plant characteristics, such as tillering, ear proliferation, and tassel seed, are selected against. Selection for good standability is also practiced.

Figure 2. Breeding system in highland pools



In October and November of each year, El Batan selections, as well as selections from Ecuador, are planted at Oriental and Estacion in Santa Catalina, Ecuador. The male composite for each pool is constituted by mixing the seed of the male selection from both El Batan and Ecuador. In March and April, the same set of half-sib families are planted at CIMMYT.

Development of highland maize populations and experimental varieties

In 1979-80, three promising materials were chosen to form the advanced unit of the highland program. These three materials were designated as populations at the Santa Catalina Station. Blanco Harinoso Precoz (BHP) is made up of the same genetic components as the male composite of Pool 1 (Figure 1). Amarillo Harinoso Precoz (AHP) originated from 1979 selections of Pool 3 at Santa Catalina. The third population, Amarillo Harinoso Intermedio (AHI), was originally named Varios x Chillos; it is an advanced generation of crosses among Chillo, Compuesto Harinoso Amararillo, Compuesto Grano Grande, Compuesto Precoz Blanco Harinoso, Compuesto Cacahuacintle, Precoz Titicaca, and Precoz Titicaca-Chihuahua. These materials underwent at least one cycle of half-sib recombination at Santa Catalina before full-sib progenies were generated. The original full-sib populations of BHP, AHP, and AHI consisted of 101, 100, and 115 families, respectively.

In May 1980, at CIMMYT, the original families of BHP and AHP were planted for progeny testing trials. At Oriental, Santa Catalina, the same families were planted in October of 1980 in the breeding nursery. By pollination time, the data were available from CIMMYT to permit the selection of the 42 best families in BHP and 47 in AHP for the regeneration of the next cycle of full-sib families. For AHI, the next cycle of full-sib families was regenerated by recombining the original 115 families without progeny tests. In 1981, at El Batan, CIMMYT, the progeny testing trials of the three populations were conducted. Tables 2, 3, and 4 show the selected family progeny trials, grown at El Batan, that were used for the formation of the three experimental varieties. Experimental varieties will be formed from each progeny testing trial from the Andean region. The same progeny testing trials were conducted at the Oriental site in 1981-82, and the trials are being harvested. These data will also be used along with El Batan data for the final across-site selection of progenies for the development of full-sibs for the next cycle of improvement. Figure 3 shows the full-sib population improvement scheme for the Andean highlands.

Lowland Maize Breeding

In the lowlands of the Andean region CIMMYT is cooperating with five countries, Bolivia, Colombia, Ecuador, Peru, and Venezuela. As in the highlands, collaboration has been in the areas of germplasm development, breeding methodology, training, workshops, and production.

CIMMYT first explored the possibilities of using, in each participating country, the improved germplasm generated in the other countries. For this, a uniform trial, ENZAT (*Ensayo Zona Andina Tropical*), was conducted in 1976-77 at six locations. The same materials were tested at three locations in 1977-78. Results indicated, in 44% of the tests (four out of nine), that CIMMYT materials were the highest yielding, that the best materials in Ecuador were the ones developed there, and that in Peru the best materials were the Bolivian. Of the Bolivian germplasm tested, 33% had CIMMYT pedigrees. The materials tested were the best varieties or hybrids available in each country. Despite high yields in some locations, however, plant architecture, particularly plant height, was excessive. Ecuadorian and Peruvian germplasm, for example, had a mean plant height at Palmira of 311 cm and 312 cm, respectively.

In 1978, a workshop was organized in Colombia, at which participants agreed to stop the ENZAT and devote more time and resources to CIMMYT IPTT, EVT, and ELVT trials. From 1975 to date, a total of 417 trials (56 of them IPTTs) have been planted in the Andean Region in the following countries:

Bolivia	101 trials
Colombia	90 trials
Ecuador	67 trials
Peru	111 trials
Venezuela	48 trials

The data and the varieties have been used in different ways in each of the Andean Region countries, reflecting the agroclimatic and socioeconomic differences which prevail.

On-Farm Research

Over the past five years, a program of on-farm research and training methodology has evolved, and is now being promoted. It is in-service oriented, combining classroom instruction and practical field experience, and consists of three training courses at the initiation of the on-farm research program, followed by one session after each harvest for three to five cycles.

The first three training courses coincide with the growing cycle of the target crop. The duration of each course is approximately two weeks, with the time being divided between lecture and field experience in which participants make on-farm surveys and plant trials on-farm. The program is divided into a training stage, during which the trainee studies survey techniques, on-farm investigation techniques, analytical techniques, and follow-up work, and an investigative stage, which also comprises survey work, agronomy, economic determination, verification of results, demonstration of a given factor, and a follow-up survey. The follow-up training courses after each harvest are for continuing education. Each course lasts approximately one week, during which data are analyzed and interpreted, and the subsequent cycle planned. Upon completion of each course, the program for the subsequent cycle is planned, trials designed, and a progress report written.

Figure 3. Proposed sequence of breeding and testing in highland populations

Planting	Breeding system
April-October El Batan, CIMMYT	**Progeny regeneration**—full-sib progenies will be regenerated from each population at El Batan. Full-sib reciprocal crosses will be made among the best selected families from the progeny trials at El Batan and Oriental, Santa Catalina.
October-July Andean Region	**International Progeny Testing Trials (IPTTs)**—Full-sib progeny (97 + 3 checks) trials will be conducted at 2 or 3 sites in the Andean region, with two replications of 10x10 simple lattice design.
April-October El Batan, CIMMYT	**Progeny Regeneration and IPTTs**—Two replications of IPTTs will be planted at El Batan; restricted reciprocal full-sib crosses will be made among the best 50% of the families, based on data from Andean IPTTs. At the same time, among the remaining 50% of the families, reciprocal full sibs will be made. Data will be obtained on plant height, ear rot, days to silk, etc., yield will only be estimated. A new set of 97 full-sib progenies wil be selected for the next cycle. If extra seeds of the progenies are available, an extra replication will be planted to develop the full sibs, the regular IPTT will not be used for this purpose.

West Africa Regional Program

A CIMMYT scientist is in the West Africa region as part of a cooperative regional effort with the International Institute of Tropical Agriculture (IITA), Nigeria, and West African national programs. With this move, CIMMYT shifted its international breeding program for streak virus resistance to the region, with full involvement of regional and IITA scientists. The maize-growing area continued to increase in Nigeria (with the largest maize hectarage in the region), Ivory Coast, Cameroon, and Ghana (Table 5). The majority of maize production is used for food, but the demand for maize for feed has increased in the last years, mainly because of a growing poultry industry.

Work on improved streak resistance is built on CIMMYT population 43, La Posta, a tropical lowland white dent material. The population is undergoing recurrent selection for yield and other agronomic characters through international progeny testing, but with emphasis on family improvement at IITA. In the second season, 1980, 250 full-sib families from La Posta were screened for streak resistance in the greenhouse. Only a few plants were identified as having some degree of streak resistance. These plants were selfed and their progenies were used in the next cycle of recombination of selected families. From the international progeny trials of La Posta in 1980, data were received from four locations, early enough to be used for selection of the next cycle of recurrent selection. Based on these data, 86 families were selected for intrafamily improvement and subsequent recombination.

In addition to these efforts within La Posta *per se*, the selected full-sib families were crossed with TZSR-W-1 in 1980 II. TZSR-W-1 is a full-season white population developed at IITA with good level of streak resistance. These crosses were advanced to F_2 under streak pressure in 1981 I, and the F_2 generation was planted and screened for resistance or tolerance to maize streak virus in 1981 II. The first backcross to the population La Posta was made by bulking pollen of selected plants in La Posta and pollinating segregants highly tolerant to maize streak virus in (La Post-TZSR-W-1)-F_2.

Experimental varieties from nine different Advanced Unit populations, which have shown good performance in Africa and have a high level of resistance to most tropical diseases except maize streak virus, are undergoing conversion to streak resistance through backcrossing. A list of the parent populations of these experimental varieties is shown in Table 6. For each backcross,

Working in cooperation with IITA in Nigeria and with various African national programs, a CIMMYT scientist is incorporating streak resistance into nine improved populations that have performed well in Africa, where periodic streak epidemics devastate farmers' maize crops

the best-performing experimental variety from the latest cycle of each of these populations is used as recurrent parent. In this manner, the program takes advantage of the continuous progress being made in the recurrent selection of each of the parent populations. After each backcross, the BC_n-F_1 generation is advanced to BC_n-F_2 under artificial streak screening. The BC_n-F_2 generation is again screened for streak resistance, and resistant segregants are used as female parents for the next backcross generation. In addition to selection for streak resistance, selection for desirable plant and grain type and maturity group of the recurrent parents is practiced in each generation. The initial crosses with the streak resistant donors (TZSR-W-1 and TZSR-Y-1 for the late-maturing varieties and TZESR-W and TZESR-Y for the early varieties) were made in 1980. During 1981, these crosses were advanced and backcrosses were made to the recurrent parents. For six of the varieties under conversion, the BC_2-F_1 generation was planted in the third season 1981. For three of the varieties, the first backcross was made in that season. Segregants with high levels of resistance to maize streak virus were obtained in the F_2 generations of these conversions.

Germplasm Testing and Development in the Region

All the countries in West Africa are now participating in CIMMYT's international testing program. They receive Experimental Variety Trials and Elite Experimental Variety Trials and are able to identify varieties with good yield potential and resistance to rust and blight. Full-season materials are needed in the longer rainy season in areas with bimodal rainfall, and in the Guinea savannah, which has one long rainy season. Varieties from populations 21, 22, 28, 29, 40, and 43 have shown good performance in these areas. Early-maturing varieties are needed in the Sudan savannah, in the shorter rainy season in areas with bimodal rainfall, and in the Coastal savannah in Ghana and Togo. Varieties from populations 30, 31, and 35 have performed well in these areas.

Several of the experimental varieties, constituted on the basis of progeny trials and including ones grown in the region, have performed well in West Africa as well as in other continents. Several experimental varieties include ones selected for seed increase by countries which have grown the Experimental Variety Trials and the Elite Experimental Variety Trials. Efforts are being made by our cooperators to fine tune these varieties under the specific conditions of their different countries. The introduction of a simple and effective system of variety maintenance and multiplication based on CIMMYT's experience in the handling of open-pollinated varieties is well under way in several countries. This system allows a rapid flow of new varieties from the research stations to the farming clientele. In addition to the direct use of the experimental varieties from the international program, these materials also are used in various other ways for improvement in the ongoing breeding programs in the region.

Other institutions involved in regional germplasm development are IITA, IRAT, and SAFGRAD (Semi-Arid Food Grain Research and Development). The CIMMYT maize breeder at IITA participated in the distribution and evaluation of progeny trials of two full-season streak-resistant populations, TZSR-W-1 and TZSR-Y-1, which were developed at IITA and tested in six different countries in West Africa in 1981. He also participated in the evaluation of regional trials distributed by IRAT and SAFGRAD. Through the SAFGRAD program, progeny testing of Pool 16 was started in the semi-arid zone in 1981.

Mideast Regional Program

A CIMMYT maize scientist, based in Turkey, works with the nine countries of the region to strengthen national population improvement research, and to introduce and test exotic germplasm for utilization in the region. On-farm testing and farmer surveys continue to receive emphasis. The region grows over 2.4 million hectares of maize and has experienced a 7 percent area increase during the last decade; total production also increased in this time period by 27 percent (see Table 7). During 1980 and 1981, CIMMYT efforts focused on three countries: Egypt, Syria and Turkey. Egypt and Turkey are the two major producers in the region, and Syria is increasing the area under maize and planning further expansion.

Maize Improvement Activities

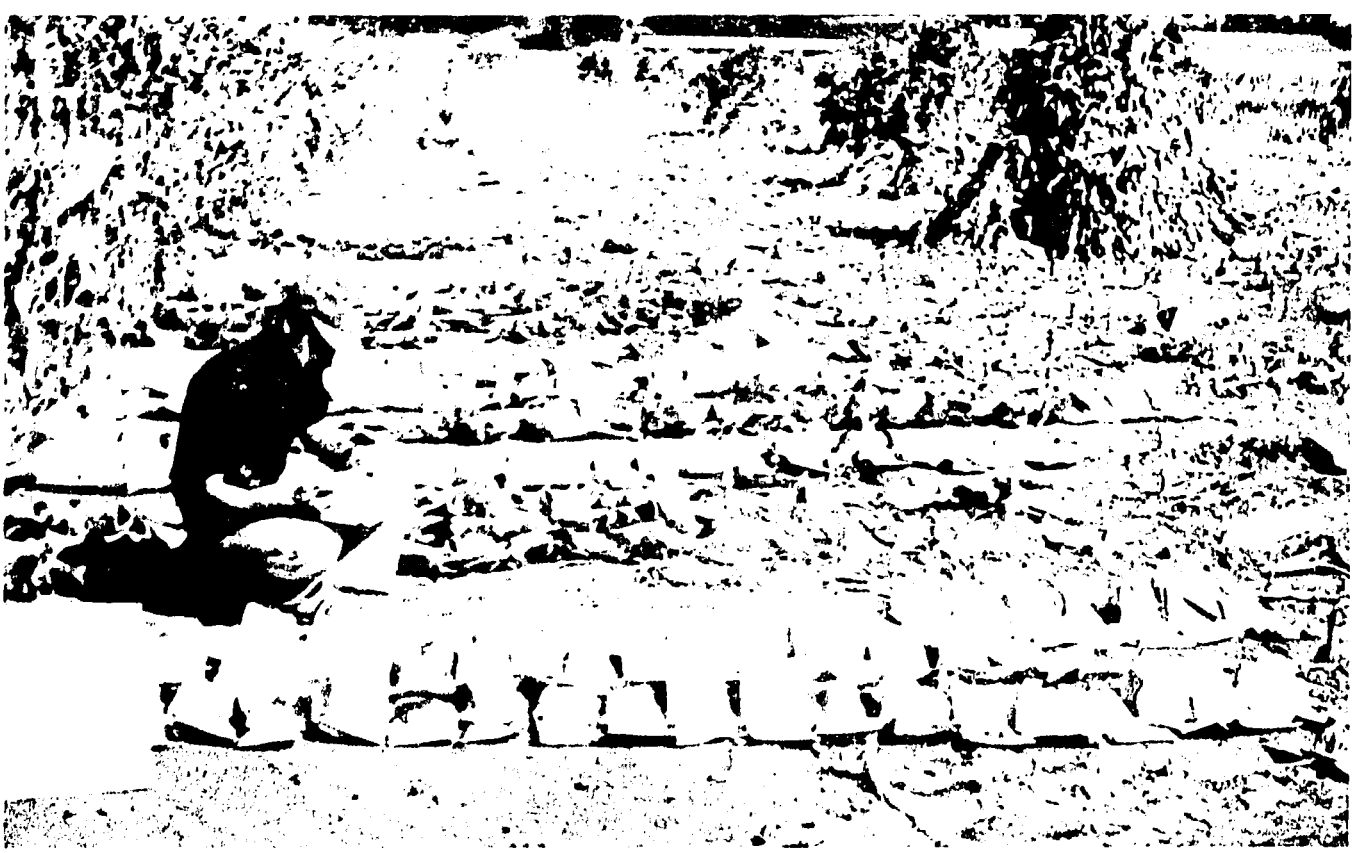
The Egyptian National Maize Program is organized to develop superior open-pollinated varieties and hybrids. The population improvement efforts continued in the two main populations: Composite-2 (tropical x local germplasm) and Composite-5 (Sids 7444). During 1980-81, an S_1/FS breeding method was employed, utilizing off-season nurseries and multi-location progeny testing. Major emphasis was on developing resistance to *Cephalosporium maydis* (late-wilt) and increasing yield. Emphasis was also given to developing resistance to *Helminthosporium turcicum* and reducing days to maturity and plant height. Trials in 1980 compared four cycles of selection and confirmed that good progress was being made in the recurrent selection program.

Activities in the hybrid program were intensified. The best combining lines came from AED and Tepalcingo-5. Good lines also have been extracted from superior families in Composite-2 and Population 29 (Tuxpeño-Caribe). Varietal cross data in 1981 showed that Sids 7734 (from Blanco Subtropical) combines well with Composite-2. Seven EVs from CIMMYT populations 21, 26, 32, 34, 42, and 44 were identified from EVTs, ELVTs, and Special Trials to serve as side-cars. Some of them will be used to contribute *H. turcicum* resistance, ear rot tolerance, and short plant type to Composite-2. Giza-2 (Composite-2 EV-2), extracted from the second cycle of selection in Composite-2, underwent large-scale testing on several thousand *feddan* (Egyptian unit of area equal to 0.42 hectares). This variety is high yielding and resistant to late-wilt. Results were encouraging, and the variety was released.

The Turkish National Maize Program strengthened and expanded its population improvement and hybrid efforts during 1980 and 1981. Movement was toward an S_1/HS breeding method coupled with multi-location progeny testing in the three populations (Samsun-1, Samsun-2, and Adapazari-1). Main breeding objectives were oriented toward developing resistance to stalk rot (*Fusarium* spp.), *H. turcicum*, and increasing yield. Artificial inoculaton, using the tooth-pick technique, was employed for the first time in 1981. Efforts also are under way to develop resistance to ECB. An early maturing population (Samsun-1) is being improved for use in the second crop program and in the mountainous regions of the Black Sea coast.

Current hybrid efforts are based on US Corn Belt germplasm. US lines were introduced and screened for adaptability, seed production capability, etc. Several promising Lancaster x Stiff-Stalk Synthetic combinations have been identified. Non-conventional hybrid approaches also were under exploration to facilitate seed production and reduce development time (e.g., Family x Line and Advanced Generation SC x Advanced Generation SC).

Testing during 1980-81 identified CIMMYT materials for use in the Program. Back-up Pool 30 and the Northern Temperate Region Pool, as well as Population 45 (Amarillo Del Bajio) and 48 (Hungarian Composite), are well adapted to Turkey and will be used to strengthen the improvement effort. Population 48 is being tested on a special cooperative basis with CIMMYT headquarters.



In nine countries of the Middle East, an area of rapid expansion in maize prodution, a CIMMYT scientist is helping national programs channel superior maize varieties into rural communities

During the 1980-81 period, three composite varieties were released, K 3/74, Ada, and Sapanca. These varieties proved superior to the existing double crosses Diker and Sakarya-66 for yield and stalk rot reaction.

The Syrian National Program is taking steps to strengthen its population improvement effort. Plans were made to form a new base population with emphasis on early maturity. The plan calls for utilizing germplasm from Pakistan, Yugoslavia, France, and CIMMYT. Preliminary observations in 1981 indicate that Population 48, CIMMYT-German Pool, NTR Pool, ITR Pool, Pool 29, and Pool 30 can be used to strengthen the population improvement effort. Most maize will be planted as a second crop following wheat, hence the need for early maturity. The open-pollinated variety Agaiti-72 from Pakistan was released in the 1980-81 period. It is a full-season material, capable of high yields.

Table 8 shows the trials and germplasm introductions sponsored by CIMMYT in eight of the Mideast countries in the 1980-81 period.

Asian Regional Program

The regional coordinator moved to headquarters in Mexico in mid-1980 and his function was partially taken over by a Rockefeller Foundation-employed pathologist-breeder located in Thailand. At that time the regional headquarters were shifted from India to Thailand in order to accelerate and enlarge breeding efforts to insert resistance to the downy mildew diseases. The Thai National Maize Program had been collaborating for several years with CIMMYT's core and special studies program on developing downy mildew-resistant materials which would be agronomically suitable for lowland tropical conditions. The downy mildew diseases have become important constraints to production during the past few years for additional countries within Asia, as well as for several countries in Latin America and Africa. The alarm caused by the spread of the diseases to several new countries and the recent success of control with resistant varieties in countries where the diseases have been endemic, and quite destructive, stimulated this added dimension to the regional effort. An agronomist-physiologist was added to the program in January 1982 and will be involved in production agronomy programs and regional in-country training.

The countries receiving greatest attention in the past continued to receive consultation, review of programs, support for training, and supply of genetic materials. These were Bangladesh, India, Indonesia, Malaysia, Nepal, Pakistan, the Philippines, Sri Lanka, and Thailand. In addition, a response to requests for visits and services from Burma and Vietnam were answered.

Some pertinent statistics on maize production for most of the countries in the region are shown in Table 9. Over the past ten years production growth has been in line with population growth in most countries. In Nepal, however, there has been a reduction in maize production; in the Philippines and Thailand, by contrast, production increases of 5.7 and 8.3 percent annually far exceed population growth. In most countries, the increase in production has resulted in an increase in maize utilization other than as direct human food, and in particular as an animal food source. Grain yields for the area are still low, ranging from 1.0 to 2.1 t/ha for the Philippines and Thailand, respectively. During the period 1961-1980, Pakistan, Indonesia, the Philippines, and China all recorded yield increases ranging from 1.2 to 2.4 per cent annually. During this period there has been considerable area expansion in Pakistan, the Philippines, Thailand, and Vietnam.

The most profound change in Southeast Asia has been the control of downy mildew diseases through the development of resistant varieties. These diseases formerly reduced yields over sizable areas by as much as 40 percent. Now large increases in production in individual countries are possible due to this genetic resistance, but there is a need to broaden the phenotypic range of materials available to meet all maize-growing requirements in the region. The development of downy mildew-resistant genotypes also has led to a vigorous input from the private sector in providing improved seed in some countries in the region.

Maize Improvement

The maize requirements for the region are diverse, as are the capacities of the various programs for carrying out maize research. The International Testing Program of CIMMYT has provided a range in terms of grain color and texture of good-yielding, management-responsive materials which are generally adapted to the region and have been released in a number of countries (e.g., Burma, Nepal, India, China, and Pakistan) by the national programs. In most countries these materials have

contributed to the breeding population while, in others (e.g., the Philippines), they have been used by the private sector in developing hybrids. More recently, due to considerable research on the development of early maturing germplasm with high yield potential (yield per day of crop), new groups of early-maturing materials are now available for testing. This is particularly important to many of the programs in the Asian region and has already led to the release of improved varieties in Pakistan.

The major limitation to the use of these improved materials in much of the area is their lack of downy mildew resistance. In 1981 CIMMYT, in cooperation with the Thai National Corn Program, began to incorporate DM resistance into three advanced unit populations while continuing the program of International Progeny Testing (IPTT). Two of these populations, Mezcla Tropical Blanco (Pop. 22) and Amarillo Dentado (Pop. 28), have shown excellent performance in many locations. Improving the level of DM resistance in these materials will not only increase their usefulness in the Asian region, but will also provide an important backstop to any DM treatment in those countries already using these materials. A third material, Amarillo Cristallino-2 (Pop. 31), is the result of considerable selection for earliness, and is now of a maturity range suitable for areas of Indonesia, Pakistan, and India. All three populations have undergone a number of cycles of within-family improvement for DM resistance in Thailand. The first set of full-sib progenies of Populations 28 and 31 were developed and dispatched from Thailand in 1981. Based on past experience, it is anticipated that 3 to 4 cycles will be required to concentrate and introgress genes for resistance.

Other problems exist, are more specific, and are being controlled through national breeding programs. General disease resistance, particularly to the stalk rots, remains a priority in most breeding programs. The corn borer is a major problem of maize production in the Philippines and Nepal, and there is a need for well-run programs, using controlled artificial infestations, to improve field tolerance. Lack of moisture at some unpredictable stage during the main growing seasons remains the major constraint to improved yields in Thailand. More stable genotypes need to be developed for these areas.

Seed Production

Six or more major international seed companies have recently become active in Thailand, the Philippines, and Indonesia. About 1500 tons of F_1 hybrid seed were sold in the Philippines in 1981; it is expected that in 1982 about 250 tons will be sold in Thailand and a lesser amount in Indonesia. A few companies are also producing seed of the better open-pollinated varieties (mainly Suwan 1 or versions of it) in the interim of developing good, adapted hybrids. The contribution from the private companies should greatly augment the effort of governments to have good seed of outstanding varieties available to growers. Hybrids may be grown on 20-25 percent of the area planted to maize by 1987 in a few countries of Southeast Asia.

National efforts in seed production are currently being helped through several bilateral arrangements. In addition, Burma and Vietnam have designated several cooperatives and state farms for seed production. Large, privately owned farms in the Philippines and in a few other countries often perform this function, producing the latest cycles of improved open-pollinated varieties.

On-Farm Research

The former regional coordinator and the regional economist have provided considerable guidance and assistance to on-farm research programs in the Chitwan District of Nepal and East Java, Indonesia. While there have been but small increases in yield during the two years of involvement, these defined areas are among the best prospective areas for obtaining an increase in production in the two countries. The lack of chemical fertilizers, good seed and a support price in Chitwan, and adequate production technology and a high yielding, downy mildew-resistant, early-maturing variety in East Java appear to be the main constraints.

The three-year, CIMMYT-sponsored, on-farm research project with G.B. Pant University, India, in the districts of Badaun, Butandshahr, and Moradabad of Uttar Pradesh province has resulted in good progress. A sound package of technology has been developed and demonstrated. Participating farmers obtained up to 124 percent increases with the new technology, compared to the traditional one. The two main improved varieties in use are as early in maturity (80-85 days) as the local varieties. Four t/ha yields were commonly obtained as compared to 1.1 t/ha for the province.

The Philippines want to change from an importer (240,000 tons in 1981) to an exporter in three years. They have initiated a yellow maize program termed "Maisagana" to reach this objective. Technology, inputs, and credit are to be simultaneously delivered to farmers. Initial success has been obtained in Calaban and South Cotabato provinces of Mindanao where the regional coordinator provided some help. Average yields were 1.5 t/ha prior to 1973 when the program began. In 1978-79, yields were 3 t/ha and in 1981 they were approaching 5 t/ha for the participating 40 to 50 percent of the farmers.

Training Activities

Forty-five maize workers from 11 countries of South and Southeast Asia received training at CIMMYT/Mexico during 1980-81. Among these, 27 received training in production, 9 in improvement (mostly breeding), 6 in experiment station operations, and 2 in quality protein laboratory techniques.

A regional field workshop was held at Farm Suwan, Thailand, during October 5-9, 1981. Special plantings were made to demonstrate maize genetic materials, techniques, and principles. These included 1) plantings of released and promising cultivars from Asian National Programs· 2) planting of the tropical and subtropical pools, populations, and two experimental varieties from each population of CIMMYT materials; 3) the effects of cultural operations, environment, chemical fertilization, and various pesticides; 4) modern procedures employed in breeding, screening for disease and insect pests, seed production, on-farm research, and extension services. Fifty-six scientists from twelve countries participated. Many requests for seed were made to individual countries and to CIMMYT following the workshop.

The regional coordinator participated in two workshops in India which dealt with procedures, techniques, and strategies for the control of stalk rot, which is quite severe during both the summer and winter growing seasons in South Asia. Each workshop was for a six-day period. Lectures, demonstrations, and practicals were held. Pathologists and breeders from 5 countries and 15 maize stations participated in the workshops. Sixteen papers on major disease subjects were presented during the second workshop. These will be printed and made available to Asian scientists.

Nine Thai maize scientists traveled to other countries in the region to review programs and assist in collecting data on CIMMYT trials sent from Thailand. Two Nepalese scientists spent 3 to 5 months in Thailand during 1980-81 in training on downy mildew resistance breeding and helping handle the material (1 hectare each year) in the collaborative program to develop good agronomic, downy mildew-resistant varieties between the Nepal and Thailand National Programs.

Table 1. Grain yield and yield stability parameters of five best experimental maize varieties across 14 locations in Central America and the Caribbean (ELVT 18A, 1981)

Variety	Stability parameter			% best check	Days to flower	Plant height
	Yield (kg/ha)	bi[a/]	S^2 di[b/]			
La Maquina 7843	5692	1.06	0.00	109	59	245
Cotaxtla 7822	5636	1.02	0.10	108	58	220
Across 7822	5570	1.13	0.00	107	58	222
Poza Rica 7843	5470	1.06	0.111*	105	59	240
Poza Rica 7921	5415	1.18*	0.15	104	58	209
Mean, best check ($\bar{x}$)	5223			100	59	235

a/ Regression coefficient
b/ Mean figure deviation from regression
* Significant at 5% level of probability

Table 2. Selected full-sib progenies for formation of an experimental variety from population Blanco Harinoso Precoz, El Batan, Mexico 1981

Progeny	Yield (kg/ha)	Rank in yield	Days to silk	Plant height (cm)	Ear height (cm)	Ear rot score[a/]	Plants harvested
14	9400	14	83	215	124	1.7	21.0
16	10769	3	86	228	118	2.7	21.5
19	7575	31	82	249	132	2.0	19.0
21	10039	9	84	237	133	1.5	21.0
23	9857	10	86	227	122	2.0	22.0
31	9492	12	86	229	122	1.7	20.5
32	10222	6	91	247	135	2.0	22.0
38	10313	5	87	243	135	2.7	21.0
92	10039	8	86	256	146	2.0	21.0
Selection mean	9745	–	86	237	130	2.0	21.0
Population mean	6822	–	87	236	128	2.4	20.2
Population range	730-12047	–	87-88	241-249	120-132	2.2-2.5	1.5-20.0
CV	16.2						
LSD 5%	2187						

a/ 1 - 5 scoring scale (1 = free from disease, 5 = very heavily infected)

Table 3. Selected full-sib progenies for formation of an experimental variety from population Amarillo Harinoso Precoz, El Batan, Mexico, 1981

Progeny	Yield (kg/ha)	Rank in yield	Days to silk	Plant height (cm)	Ear height (cm)	Ear rot score[a]	Plants harvested
2	7301	25	88	212	106	1.7	21.5
6	12047	1	88	233	125	2.2	22.0
13	8762	6	85	221	135	2.5	22.0
15	7758	19	87	225	118	2.5	20.0
29	8762	7	85	231	138	1.2	22.0
45	8396	12	89	236	123	1.7	20.5
54	9492	2	89	228	124	1.7	21.0
84	7393	24	85	231	126	2.2	18.5
107	7758	20	85	230	121	2.2	20.5
122	8123	16	88	219	134	2.0	20.0
Selection mean	8579	–	87	227	125	2.0	20.8
Population mean	5997	–	87	225	126	2.8	20.0
Population range	2008-12047	–	88	205-233	106-125	2.2-4.0	16.0-22.0
CV	15.8						
LSD 5%	1871						

a/ 1 - 5 scoring scale (1 = free from disease, 5 = very heavily infected)

Table 4. Selected full-sib progenies for formation of an experimental variety from population Amarillo Harinoso Intermedio (Varios x Chillos), El Batan, Mexico, 1981

Progeny	Yield (kg/ha)	Rank in yield	Days to silk	Plant height (cm)	Ear height (cm)	Percent ear rot	Plants harvested
2	9671	4	98	252	141	24.2	19.5
3	8877	17	93	250	133	24.2	20.5
11	7440	51	95	208	113	15.8	17.5
31	8922	15	97	244	140	40.0	19.5
70	9511	6	91	238	125	17.6	19.5
76	7938	30	96	237	131	32.5	18.5
80	7552	46	92	243	148	17.2	21.0
89	8896	16	98	244	134	25.9	18.0
95	8506	20	101	255	156	30.9	17.5
166	9066	13	96	257	128	9.0	21.0
Selection mean	8638	–	96	243	135	23.7	19.3
Population mean	5921	–	97	250	142	34.7	18.6
Population range	1946-10832	–	92-95	237-281	141-151	13.7-39.3	11.5-20.5
CV	18.1						
LSD 5%	2117						

Table 5. Area, yield, and production of maize in West African countries with more than 50,000 hectares of maize area

Country	Area harvested (000 ha)	Yield (kg/ha)	Production (000 tons)
Nigeria	1665	990	1500
Ivory Coast	575	478	275
Cameroon	535	897	480
Guinea	420	762	320
Benin	350	657	230
Ghana	340	1118	380
Upper Volta	120	667	80
Togo	115	1348	155
Mali	90	667	60
Senegal	50	1000	50

Source: FAO Production year Book, 1979

Table 6. Parent populations of experimental varieties undergoing conversion to streak resistance, West Africa, 1980-81

Parent population	Pop. no.	Description	Adaptation
Mezcla Tropical Blanca	22	Late white semident	Lowland tropics
Amarillo Dentado	28	Late yellow dent	Lowland tropics
Tuxpeño Caribe	29	Late white dent	Lowland tropics
Blanco Cristalino-2	30	Early white flint	Lowland tropics
Amarillo Cristalino-2	31	Early yellow flint	Lowland tropics
Antigua x Recublica Dominicana	35	Intermediate yellow dent	Lowland tropics
White QPM	40	White semiflint	Lowland tropics
La Posta	43	Late white dent	Lowland tropics
AED x Tuxpeño	44	Late white dent	Mid-altitude and subtropical areas

Table 7. Maize area, yield, production and imports of countries of the Middle East and North Africa which produce at least 25,000 hectares of maize

Country	Area (000 ha)		Yield (kg/ha)		Production (000 tons)		Imports (000 tons)	
	1969-71	1980	1969-71	1980	1969-71	1980	1969-71	1980
Afghanistan	453	460	1560	1733	707	797	0	0
Egypt	634	802	3741	4029	2370	3230	52	596
Iran	25	42	1400	1429	35	60	25	680
Iraq	6	35	1495	1857	9	65	2	200
Morocco	474	411	801	810	380	333	1	115
Sudan	39	61	780	738	31	45	0	0
Syria	6	31	1403	2258	8	70	1	100
Turkey	646	550	1637	2091	1058	1150	3	0
Yemen AR	8	64	1975	1478	16	95	0	5
Totals	2291	2456			4616	5845	84	1696
Weighted means			2014	2380				

Source: Data for area, yield and production: FAO Production Yearbook, 1981
Data for imports: FAO Trade Yearbooks, 1972 and 1980

Table 8. CIMMYT-sponsored trials and germplasm introductions into the Middle East and North Africa, 1980 and 1981

Trial or introduction	Country								Total no. of sets
	Egypt	Jordan	Morocco	Saudi Arabia	Sudan	Syria	Turkey[a]	Yemen AR	
IPTT-34	1								1
IPTT-45							1		1
IPTT-47	1								1
POP-44	2								2
POP-48							1		1
QMPT-11B	2						3		5
EVT-12	1								1
EVT-14A	1			1					2
EVT-14B				1					1
EVT-15A				1					1
EVT-15B				1			2		3
EVT-16	2	1		1					4
ELVT-18A	1				1			3	5
ELVT-18B	1				1			3	5
ELVT-19	1								1
ELVT-20	2	1	1	1			9		14
Special nursery	2					1	5		8
Total no. trials	17	2	1	6	2	1	21	6	56

[a] Germplasm (lines, populations, etc.) was obtained by CIMMYT from several US institutions and introduced into Turkey

Table 9. Maize production and consumption in eight counties in CIMMYT's Asian Regional Program, 1978 to 1980

Country	Production				Consumption		
	Average (000 t)	Growth rate (%/yr)	Area growth (%/yr)	Yield growth (%/yr)	Population growth (%/yr)	Utilization growth (%/yr)	Growth of maize as food supply (%/yr)
India	6066	1.7	1.4	0.4	2.0	1.6	0.3
Nepal	665	−1.5	0.2	−1.7	2.2	−1.5	−3.4
Pakistan	832	3.0	1.8	1.2	3.1	3.1	0.5
Indonesia	3645	1.6	−0.1	1.7	1.8	1.5	−1.8
Philippines	3187	5.7	3.4	2.4	2.7	6.1	3.3
Thailand	3097	8.3	7.8	0.5	2.7	15.5	a/
Vietnam	500	3.1	3.0	0.1	2.9	3.0	−1.5
China	37000	2.2	1.0	1.2	1.6	1.8	−0.2

a/ Direct consumption of maize in Thailand is negligible

Source: World Maize Facts and Trends, report 1. 1981. CIMMYT.

Training

In 1980 and 1981, 120 in-service trainees from 38 countries participated in CIMMYT's maize training program, specializing in one of four areas, maize improvement, maize production research, experiment station operations, and maize quality laboratory techniques. A breakdown of trainee numbers by country and specialization is provided in Table 1.

A description of the overall strategy for maize production research that is used in the training program is provided in the CIMMYT Report on Maize Improvement 1976-77. Further information on the training activities in the four areas of specialization mentioned above are given in the CIMMYT Report on Maize Improvement 1978-79. While the training continues to evolve to meet perceived needs, those two earlier accounts still suffice.

Current Emphasis

Recently, it has become more evident that seed production is a serious bottleneck to increasing maize production in developing countries. Many countries which work with CIMMYT's maize program utilize open-pollinated maize varieties, for which there is almost no literature on seed production. Considerable literature exists, however, on seed production of hybrid maize. For these reasons, CIMMYT's maize program has increased its emphasis on seed production aspects of open-pollinated varieties. As a part of this new emphasis, during the four cycles reported here, the maize training program has exposed all trainees to the various stages of seed multiplication and variety maintenance that are required with open-pollinated maize varieties. Primary emphasis is given to variety maintenance and the early multiplication stages of breeder and foundation seed, because these stages are usually under the control of research personnel in national programs. Then trainees are shown how the multiplication factors can result in seed quantities adequate to cover tens of thousands of hectares in very few crop cycles. Organizational aspects for the achievement of these goals are considered. However, the majority of the time spent on seed production is in the practical aspects of varietal maintenance and seed multiplication plots. These activities are conducted both on CIMMYT's experiment stations and in farmers' fields, to produce seed of experimental varieties required for CIMMYT's international variety trials or for the on-farm research conducted by the trainees in maize production research.

Much of the maize production research conducted by the trainees during this period was carried out under zero tillage management technology. This research confirmed earlier indications that zero tillage with the use of herbicides is suitable for maize production in the lowland tropics. In an area where the climate and soils make the timing of cultural operations critical, the use of zero tillage permits more timely management through the effects of the mulch of previous crop residues. This is particularly beneficial at planting time. The beneficial effects of reduced tillage, combined with mulch and an effective use of herbicides, are well known. They include reduced soil erosion, improved water-use efficiency, lower soil temperatures, improved soil structure, and a lower weed seed burden in the surface layer of soil. Yields under zero tillage in the trainees' experiments have generally been equal to or higher than those from systems employing more conventional cultural practices.

The training program is cooperating with small farmers (1 to 20 hectares) who usually have to rent tractor power for cultivation of the land or

CIMMYT trainees gain valuable direct experience in techniques of crop improvement and other aspects of agricultural research and production

who plant with a simple planting stick. Most farmers try to control weeds during the crop cycle by hoeing. Labor is scarce in the area so family labor can only attempt to control the weeds on 1 to 2 hectares of maize per crop season when cultivation is in the conventional manner. Farmers have increased this area three- and four-fold by the adoption of zero tillage and the use of herbicides (paraquat and atrazine applied with a knapsack sprayer). At the same time, their yields have increased two to three times due to the more effective weed control. These yield and management advantages are reflected clearly in the economics of maize production in the zone, and in the elimination of much of the drudgery involved. Obviously, modifications will have to be made in zero tillage management under different soil and climatic conditions, but experience in the maize training program indicates that it offers great promise for improving tropical maize production.

CIMMYT's economics program also brings trainees to Mexico. These trainees are usually economists associated with their national maize or wheat programs. Twenty-one such economists associated with maize programs came to CIMMYT during 1980-81. The main emphases of their training were the methodology, execution, and interpretation of farmer surveys to ascertain farmer circumstances, as an aid to planning on-farm agronomic research, and the economic interpretation of agronomic data from on-farm experiments. These trainees spend a proportion of their time with the maize production research trainees to get a feel for field aspects of an on-farm agronomic research program. Some groups also carry out their survey field work in the same area.

In order to follow up with former trainees and increase the number of trained production agronomists in the world, CIMMYT's maize training agronomists have given support to a number of regional and national training programs during 1980 and 1981. Three visits were made to Ecuador in 1980 to participate in an intermittent training course in the province of Manabí. Single visits were made to Nicaragua and Pakistan for in-country training courses, and to Kenya for a regional training course in on-farm research with participants from 12 African countries. CIMMYT's regional scientists or CIMMYT scientists assigned to work with national programs were involved in all of these training activities, as were some former CIMMYT trainees.

In the classroom, trainees incorporate theory with practical experience gained in the field

Table 1. Countries represented by maize in-service trainees, CIMMYT, Mexico, 1980 and 1981

Country	Training program			
	Maize improvement	Maize production research	Experiment station operation	Maize quality laboratory techniques
Bangladesh	2	2		
Belize		1		
Botswana		1		
Burma	1			
Cape Verde Islands		1		
Colombia	2	2		
Dominican Republic		2		
Ecuador		1		1
Egypt	1	1		
Ethiopia	2	1		
Ghana	5	9	1	
Guatemala				1
Haiti		2		
Honduras		1		
Hungary	1			
India		1		
Indonesia	1	2		
Japan		2		
Kenya	1	1		
Malawi	1	2		
Malaysia		2		
Mexico		9		
Mozambique		3		
Nepal		2		
Nicaragua		2		
Pakistan	2	6	3	2
Panama		2		
Peru	1	3		
Philippines		2		
Swaziland		1		
Tanzania		2		
Thailand	1	8	3	
Transkei		1		
Turkey	4			1
Venezuela	1			
Vietnam	2			
Zaire		3		
Zambia	1	1		
Total	29	79	7	5
Grand total 120				

The International Maize and Wheat Improvement Center (CIMMYT) is an internationally funded, nonprofit scientific research and training organization. Headquartered in Mexico, CIMMYT is engaged in a worldwide research program for maize, wheat and triticale, with emphasis on food production in developing countries. CIMMYT is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), and the United Nations Development Programme (UNDP). The CGIAR consists of 50 donor countries, international and regional organizations, and private foundations.

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